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Abstract

Analytical and computational models of fiber reinforced composite materials are constructed using a mathematical procedure called *homogenization*. The procedure is systematic; i.e., one can estimate the precision of the approximations to the field equations of the composite. Moreover, it retains interaction effects due to the microstructure of the composite in the macroscopic approximations. A software system, MeMCAP, based on finite element methods implements the methodology for evaluation of macroscopic effective moduli of the composite and for computation of the microscopic stress and strain fields acting at the fiber–matrix interfaces. The software system is designed for easy use by engineers who need not be familiar with the underlying analytical techniques. Interaction takes place through a menu–driven control structure which requires specification of the material properties of fiber and matrix and of the "geometry" of a typical cell of the composite. The homogenization method produces an *effective parameter model of* the macroscopic behavior of the material (longitudinal and transverse Young's moduli, Poisson coefficients, etc.), and a description of the microscopic distributions of stress within the cell – especially at the fiber–matrix interface. The system can treat composites with various fiber shapes and packing arrangements. It can also treat multi-ply laminates. The program, written in Fortran, is fast and efficient. Extensions of the work to encompass dynamical phenomena such as the propagation and dispersion of stress waves, thermal properties, and estimation of the onset of fractures are also discussed. (SDIO)

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1 Introduction and Project Summary

The objective of this project is the development of analytical methodology implemented in a software tool for the modeling and design of composite materials. Our ultimate objective is to provide a software system for engineering level evaluation of composites in a form which is easy to use, reasonably comprehensive, flexible, extensible, portable and computationally efficient. To this end we have developed a prototype program for the evaluation of effective elasticity moduli for fiber–reinforced composites which includes the capability to compute an approximation to the microscopic distribution of stresses at the fiber–matrix interface.

1.1 Modeling Composite Materials

Direct computation of the detailed behavior of composites under loads is virtually impossible using conventional methods, including sophisticated finite element codes. This is a consequence of the large number of degrees of freedom in the heterogeneous material. A computational procedure which has proven useful is to derive a model representation with material coefficients which do not vary (rapidly) in spatial variables – in effect to find a homogeneous material whose macroscopic behavior approximates that of the composite in a specifc context. Many techniques have been used for the derivation of homogeneous, continuum approximations of composite materials.[1] In this report we shall focus on the homogenization method, particularly as developed in [5,6,7] and in the general sources [12,35,65]. This is a powerful mathematical technique for the analysis of physical systems in which there are two or more scales upon which spatial or temporal (or both) phenomena occur. In a composite medium the natural scales are the small (microscopic) scale of interfiber spacing in fiber reinforced materials, or the mean free path length between particles in particle reinforced composites; and the large (macroscopic) scale characterizing the overall dimensions of the structure formed by the medium.

This report presents two basic results from application of the homogenization method to the analysis of fiber—reinforced composite materials:

[1] See among many other references [1,2,3,22,23,74].

1. When the period (dimension) of a basic "cell" of the periodic structure approaches zero, the fields of deformations and stress of the composite tend to those corresponding to a homogeneous (anisotropic) structure. The complete set of moduli for the homogenized structure can be computed in terms of the elastic moduli of the constituents (fibers and matrix) and the parameters describing the geometrical layout of a single "period" or "cell" of the composite structure.

2. By retaining additional terms in the homogenization asymptotic analysis, we can develop a picture of the local distribution of stresses in the material, e.g., at the interfaces between the fibers and matrix. (See Figure 1 and the examples in Section 4.)

The homogenization procedure is *systematic*; i.e., one can estimate the precision of the approximations to the field equations of the composite. Moreover, unlike the "rule of mixtures," it retains interaction effects due to the microstructure of the composite in the *macroscopic approximations. Numerical evaluation* of both the homogenized moduli and the distributions of local stresses can be based on finite element analysis of elliptic partial differential equations.

The homogenization procedure is *general* in the sense that it can treat both materials with a regular, periodic infrastructure and materials with a random infrastructure. The general form of the analysis is similar in both cases, as is the form of the expressions for the effective parameters in the approximations; of course, the details of the derivations are quite different.[2]

In this Phase I project we have developed a prototype software system based on finite element methods to implement the homogenization methodology the evaluation of macroscopic effective moduli of composites with periodic infrastructure and for computation of the microscopic stress and strain fields acting at the fiber–matrix interfaces. The software system is designed for easy use by engineers who need not be familiar with the underlying analytical techniques. Interaction takes place through a menu–driven "supervisor" program which requires specification of the material properties of fiber and matrix and of the "geometry" of a typical cell of

[2]The general theories for the periodic and random cases are developed in [12] and [59], respectively.

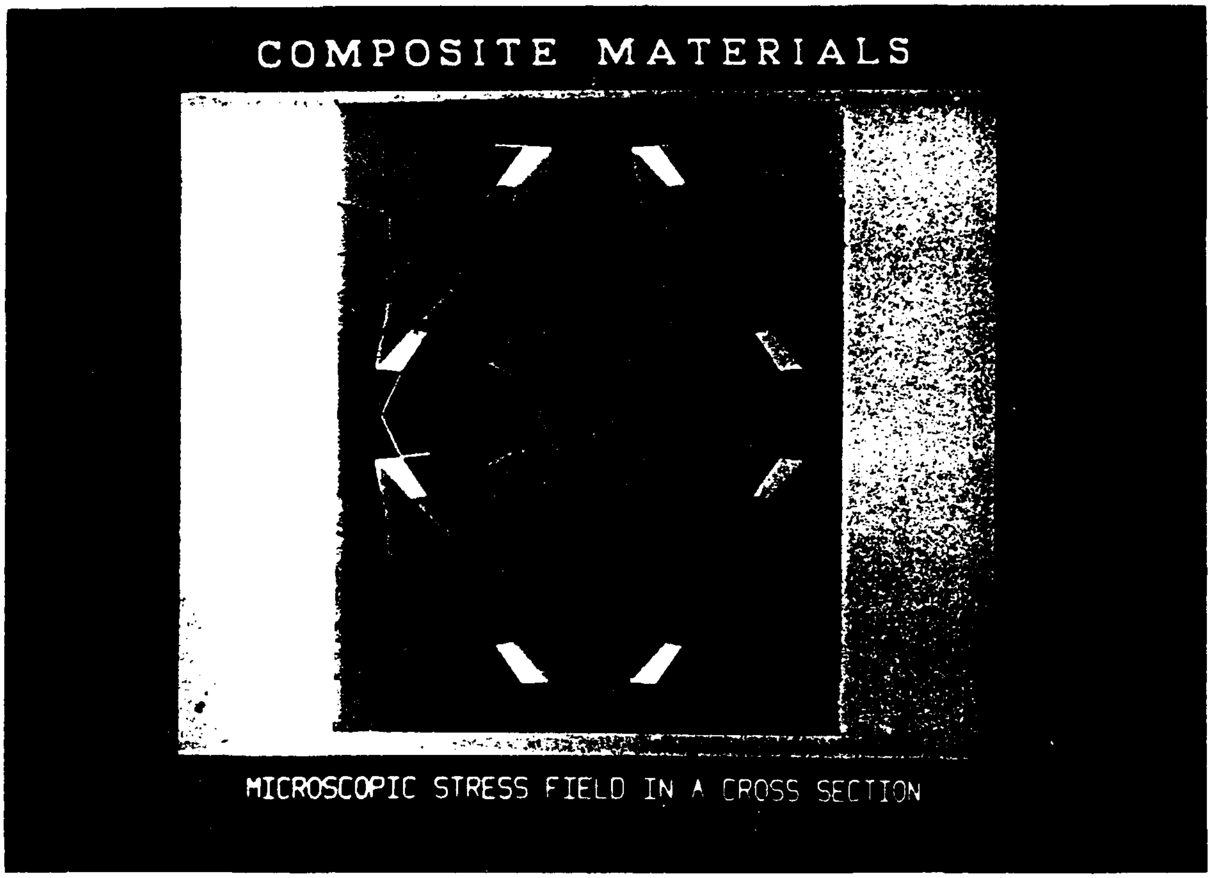

Figure 1: Microscopic stress field in a cross section of a typical cell computed by homogenization.

the composite. The homogenization method produces an effective parameter model of the macroscopic behavior of the material (longitudinal and transverse Young's moduli, Poisson coefficients, etc.), and a description of the microscopic distributions of stress within the cell – especially at the fiber–matrix interface. The system can treat composites with various fiber shapes and packing arrangements. It can also treat multi-ply laminates. The program, written in Fortran, is fast, efficient, and portable. It can be readily extended to treat other types of composites, and it can be enhanced to incorporate a database of composite properties for comparison with predictions of the analytical models. We plan to implement these extensions and enhancements in the second phase of this project.

1.2 Project Summary

The results of the project fall into two classes:

1. Analytical results on the derivation of the "homogenized approximations" for the elastic response of fiber–reinforced composites in the periodic case, including asymptotic expansions of the stress, strain, and displacement fields; and
2. Implementation of the effective parameter models and field expansions in a menu–driven software system.

The analytical results are summarized in the next section. The software system is described in section 3. Sample numerical results from the software system are given in section 4 and Listings 1 and 2 at the end of the report. Recommendations for further research are given section 5.

1.3 Comments on Some Related Work

The need for tools for stress analysis of laminates formed from composites as a basis for the evaluation of strength and failure properties has been emphasized by

many researchers, see for example [71]. As pointed out in [71], difficulties have been encountered in treating systems containing multiple layers. As we show in section 3 (see also [5]), the homogenization method readily handles such cases, even when the number of layers in the laminate is large.

2 The Homogenization Method for Modeling Composite Materials

2.1 Formulation of the Model

Consider the problem of characterizing small scale elastic deformations of a composite material which, in its undeformed state, occupies a region Ω, open and bounded in $\Re^3$ with regular boundary Γ. Suppose the boundary is partitioned into $\Gamma = \Gamma_0 \cup \Gamma_1$. (See Figure 2.) Suppose the material is constrained (not to move) along the Γ_0 portion of the boundary, and that a surface force $g = [g_1(x_1,x_2,x_3), g_2(x_1,x_2,x_3), g_3(x_1,x_2,x_3)]$ is incident on the material along the Γ_1 portion of the boundary. Suppose in addition there are volumetric forces $f = [f_1(x_1,x_2,x_3), f_2(x_1,x_2,x_3), f_3(x_1,x_2,x_3)]$ acting on the interior of the body.

Let $u(x_1,x_2,x_3) = [u_1(x_1,x_2,x_3), u_2(x_1,x_2,x_3), u_3(x_1,x_2,x_3)]$ be the displacement field of the body subjected to the force densities f, g. Then

$$e_{ij}(u) = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right), \quad 1 \le i,j \le 3 \tag{1}$$

defines the *strain tensor*. The *stress tensor* is σ_{ij} which satisfies the equilibrium equations

$$\frac{\partial \sigma_{ij}}{\partial x_j} + f_i = 0 \text{ in } \Omega \tag{2}$$

$$\sigma_{ij} n_j = g_i \text{ on } \Gamma_1 \tag{3}$$

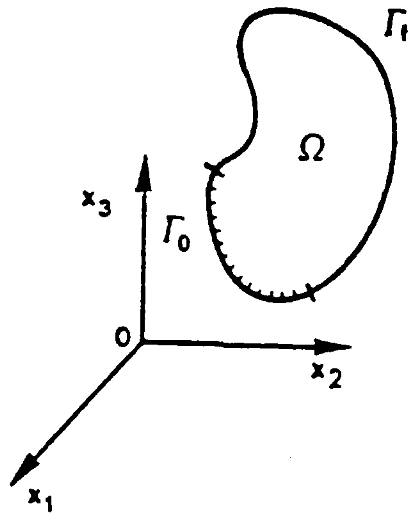

Figure 2: Elastic body subjected to forces.

Stress and strain are related by the pointwise constitutive relation[3]

$$\sigma_{ij}(u) = a_{ijk\ell}(x_1, x_2, x_3)e_{k\ell}(u), \quad 1 \leq i, j \leq 3 \tag{4}$$

The components of the *elasticity tensor* $a_{ijk\ell}(x_1, x_2, x_3)$ are bounded and satisfy

$$\text{symmetry} \quad a_{ijk\ell} = a_{jik\ell} = a_{ij\ell k}, \quad 1 \leq i, j, k, \ell \leq 3$$

$$\text{positivity} \quad \sum_{i,j,k,\ell=1}^{3} a_{ijk\ell}\xi_{k\ell}\xi_{ij} \geq \alpha \sum_{i,j=1}^{3} |\xi|^2,$$

$$\text{for some} \quad \alpha > 0, \text{ and for all } \xi_{ij} \text{ such that } \xi_{ij} = \xi_{ji}$$

In composite materials with a periodic infrastructure of fibers, cells, or layers, etc., the elasticity tensor will be a periodic function of the spatial variables. The homogenization method is suitable for treating the case when the infrastructure of the composite is "fine" relative to the macroscopic dimensions of the structure. The periodic structures treated here can be simple identical rectangular or hexagonal arrangements, or they can be more complex shapes as shown in Figure 3. The only constraint is that the opposing faces of a typical "cell" of the structure which correspond through a translation can be identified in pairs.

[3]In the following, we use the convention that repeated indices are summed.

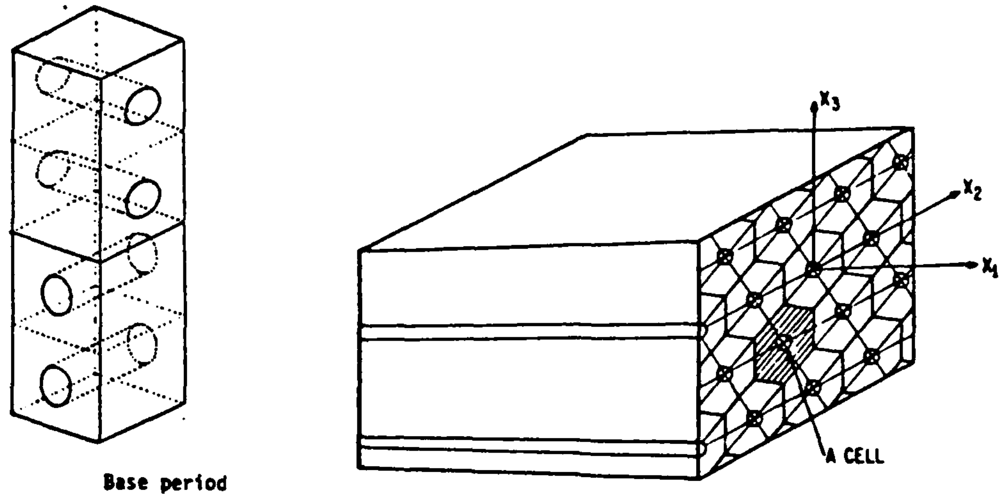

Figure 3: Typical periodic cross-sections of composites for the homogenization method.

Let Y be a dimension of a typical cell of the structure, and suppose that the structure, i.e., the overall composite, consists of a large number of cells. Let ϵ be a small dimensionless parameter that is the (homothetic) ratio of Y to a typical dimension of the structure as a whole.[4] If the spatial variable $x \in \Re^3$ is used to describe the macroscopic variations in the material, then we use $y = x/\epsilon$ as the microscopic spatial scale which describes rapid variations of the elasticity across the structure.[5] Hence, it is appropriate to identify

$$a^{\epsilon}_{ijk\ell}(x_1, x_2, x_3) = a_{ijk\ell}(y), \qquad y = \frac{x}{\epsilon}. \tag{5}$$

Introducing the shorthand notation,

$$a(y) = \{a_{ijk\ell}(y)\}, \qquad a^{\epsilon}(x_1, x_2, x_3) = a(\frac{x}{\epsilon})$$

[4]For example, if the composite structure is a fiber reinforced rod of length L and thickness W, and if a typical cell of the rod is defined to be a section of the rod including a single fiber and a portion of the surrounding matrix, and if the cell cross section as length Y, then $\epsilon = Y/W$. Hence, ϵ is dimensionless, and assuming there are many cells in the cross section of the rod, $0 < \epsilon << 1$.

[5]Using the composite rod example, if we move the small distance of $x = \epsilon$ units through the cross section of the rod, we will pass from matrix to fiber and back to matrix, incurring a significant variation of elasticity. This corresponds to a movement of one unit in the fast spatial scale y.

$$\sigma = \{\sigma_{ij}\}, \quad e(u) = \{e_{k\ell}(u)\}$$

the constitutive law (4) is written

$$\sigma_{ij} = a^{\epsilon}_{ijk\ell}(x_1, x_2, x_3) e_{k\ell} \tag{6}$$

where

$$e(u) = \{e_{ij}(u)\}, \quad e_{ij}(u) = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$$

When an ambiguity is possible, either $e_x(u)$ or $e_y(u)$ will be specified depending on whether the derivative is with respect to x or y. The boundary conditions are:

$$u = 0 \text{ on } \Gamma_0 \quad \sigma_{ij} n_j = g_i \text{ on } \Gamma_1 \tag{7}$$

The problem posed by (1)–(4) has a unique solution which depends on ϵ and which we shall designate as u^{ϵ}; a stress field σ^{ϵ} may be associated with this:

$$\sigma^{\epsilon} = a^{\epsilon}(x) e(u^{\epsilon}) \tag{8}$$

When ϵ is small, it is very difficult to calculate u^{ϵ} numerically since there are a large number of heterogeneities in the elastic medium. Therefore, one usually tries to obtain an expansion of the solution u^{ϵ} and the stress field σ^{ϵ}.

2.2 The homogenization method

The homogenization method results in replacing the pointwise constitutive relation (6) by a linear relation (with coefficients constant in space) between the "mean values" of the stress and strain tensors.[6]

[6]It is important to emphasise that the method applies not only to systems with a periodic structure, but also to systems with a structure which varies randomly in space. The random variations must be stationary in a strong sense, and the details of the arguments differ from the periodic case; however, the principles are similar. See [59] for the general theory in the random case and [10,50] for extensive applications.

2.2.1 Asymptotic Expansions

The solution depends on two scales:

(i) The first is the macroscopic dimension (scale) of Ω which affects the solution through the forces applied to the body as whole and the conditions at the boundaries.

(ii) The second is due to the period of the microscopic system infrastructure which characterizes the local internal forces and stress distributions.

This justifies looking for an asymptotic expansion of the solution the form:

$$u^{\epsilon} = u^{0}(x,y) + \epsilon u^{1}(x,y) + \epsilon^{2}u^{2}(x,y) + \cdots \tag{9}$$

where the $u^{\epsilon}(x,y)$ are, for each $x \in \Omega$, Y-periodic functions with respect to the variable $y \in Y$. Then $y = x/\epsilon$ in (9) is the "fast" local scale of the internal structural variations, i.e., x scaled by the (normalized) distance between fibers. An expansion of the deformation field $e(u^{\epsilon})$ may also be identified

$$e(u^{\epsilon}) = \frac{1}{\epsilon}e_{y}(u^{0}) + e(u^{0}) + e_{y}(u^{1}) + \epsilon[e_{x}(u^{1}) + e_{y}(u^{2})] + \cdots \tag{10}$$

and the associated stresses field has the representation

$$\sigma^{\epsilon} = \frac{1}{\epsilon}\sigma^{0}(x,y) + \sigma^{1}(x,y) + \epsilon\sigma^{2} + \cdots \tag{11}$$

with

$$\begin{aligned} \sigma^{0} &= a(y)e_{y}(u^{0}) \\ \sigma^{1} &= a(y)[e_{y}(u^{1}) + e_{x}(u^{0})] \\ \sigma^{2}(x,y) &= [e_{y}(u^{2}) + e_{x}(u^{1})] \end{aligned}$$

The equilibrium equations (2) applied to σ^{ϵ} give

$$\frac{\partial \sigma^{\epsilon}_{ij}}{\partial x_{j}} + f_{i} = 0$$

or in a more condensed form

$$\text{div } \sigma^\epsilon + f = 0 \tag{12}$$

Given the expansion (11) of σ^ϵ we have

$$\frac{1}{\epsilon^2}\text{div}_y\sigma^0 + \frac{1}{\epsilon}\left(\text{div}_y\sigma^1 + \text{div}_x\sigma^0\right) + \text{div}_y\sigma^2 + \text{div}_x\sigma^1 + f + \cdots = 0 \tag{13}$$

$$x \in \Omega, \quad y \in Y$$

where

$$\text{div}_y\sigma^{(\alpha)} = \left\{\frac{\partial\sigma_{ij}^\alpha}{\partial y_j}\right\}, \quad \text{div}_x\sigma^{(\alpha)} = \left\{\frac{\partial\sigma_{ij}^\alpha}{\partial x_j}\right\}$$

The boundary conditions (3) are treated in the same way:

$$\frac{1}{\epsilon}\sigma^0 \cdot n + \sigma^1 \cdot n - g + \epsilon\sigma^2 \cdot n + \ldots = 0, \quad x \in \Gamma_1, \quad y \in Y \tag{14}$$

Finally, the conditions (7) mean that

$$u^0 + \epsilon u^1 + \epsilon^2 u^2 + \ldots = 0, \quad x \in \Gamma_0, \quad y \in Y \tag{15}$$

By making the various powers of ϵ zero we obtain:

$$\left\{\begin{array}{rcl} \text{div}_y\sigma^0 & = & 0 \\ \sigma^0 & = & a(y)e_y(u^0) \end{array}\right. \tag{16}$$

$$\left\{\begin{array}{rcl} \text{div}_y\sigma^1 + \text{div}_x\sigma^0 & = & 0 \\ \sigma^1 & = & a(y)[e_y(u^1) + e_x(u^0)] \end{array}\right. \tag{17}$$

$$\left\{\begin{array}{rcl} \text{div}_y\sigma^2 + \text{div}_x\sigma^1 + f & = & 0 \\ \sigma^2 & = & a(y)[e_y(u^2) + e_x(u^1)] \end{array}\right. \tag{18}$$

The equations (14) and (15) will be used later.

2.2.2 Analysis of the Asymptotic Expansion

The systems (16)–(18) contain differential operators in y. They are equations with partial derivatives relative to the macroscopic spatial scale x with the associated period Y; and so, the unknown factors are Y-periodic functions.

System (16): This leads immediately to:

$$\sigma^0 = 0, \quad u^0 = u^0(x) \tag{19}$$

System (17): In view of (19) it reduces to:

$$\text{div}_y \sigma^1 = 0, \quad \sigma^1 = a(y)[e_y(u^1) + e_x(u^0)] \tag{20}$$

The deformation $e_x(u^0)$ is a function of x and not y; therefore, it plays the role of a parameter with respect to the differential system in y. As a consequence of linearity, σ^1 and u^1 may therefore be written in the form:

$$\begin{cases} \sigma^1 &= s^{k\ell}(y) e_{k\ell}(u^0) \\ u^1 &= \chi^{k\ell}(y) e_{k\ell}(u^0) \end{cases} \tag{21}$$

where

$$\begin{cases} \text{div}_y s^{k\ell} &= 0 \\ s^{k\ell} &= a(y)[\tau^{k\ell} + e_y(\chi^{k\ell})] \\ e_{k\ell}(u^0) &= \frac{1}{2}\left(\frac{\partial u_k^0}{\partial x_\ell} + \frac{\partial u_\ell^0}{\partial x_k}\right) \\ \chi^{k\ell} & \text{is} \quad Y\text{-periodic} \end{cases} \tag{22}$$

The tensor $\tau^{k\ell}$ is the unit tensor.

It can be shown that the system (22) determines the vector $\chi^{k\ell}(y)$ to within an additive constant.

For any function $\phi = \phi(x, y)$, we define the averaging operation

$$<\phi> = \frac{1}{meas(Y)} \int_Y \phi(x, y) dy$$

The solution σ^1 of (17) is given by,

$$\sigma^1(x, y) = a(y)[\tau^{k\ell} - e_y(\chi^{k\ell})] e_{k\ell}(u^0) \tag{23}$$

and taking the mean value, we obtain,

$$<\sigma_{ij}^1> = q_{ij}^{k\ell} e_{k\ell}(u^0) \tag{24}$$

where

$$q_{ij}^{k\ell} =< a_{ijk\ell}(y) > - < a_{ijpq}(y)e_{pq}(\chi^{k\ell}) > \tag{25}$$

System (18): It suffices to take the mean over a period Y in the first equation to obtain:

$$\mathrm{div}_x < \sigma^1 > + f = 0 \text{ in } \Omega \tag{26}$$

If we introduce $\Sigma =< \sigma^1 >$, we have

$$\begin{cases} \mathrm{div}_x \Sigma + f & = \ 0 \text{ in } \Omega \\ \Sigma_{ij} = q_{ij}^{k\ell} e_{k\ell}(u^0) & \end{cases} \tag{27}$$

Using equation (15) and taking the mean on Y in (14), we obtain:

$$\begin{cases} u^0 = 0 & \text{on} \quad \Gamma_0 \\ \Sigma \cdot n = g & \text{on} \quad \Gamma_F \end{cases} \tag{28}$$

The system (27) with boundary conditions (28) is a well posed elasticity problem; the equilibrium equations are unchanged, as well as the boundary conditions. The elastic constitutive relation is

$$\Sigma_{ij} = q_{ij}^{k\ell} \cdot e_{k\ell}(u^0) \tag{29}$$

It is homogeneous since the coefficients $q_{ij}^{k\ell}$ given by (25) are independent of $x \in \Omega$. These coefficients define the equivalent "homogeneous" material. They are called *homogenized* or *effective coefficients.*

Note: *The effective parameters q (25) include not only the averages of the a(y), the "rule of mixtures" which one expects, but also terms which "correct" for local interactions. These correctors are usually omitted in naive effective medium theories [3].*

The stress field $\Sigma = \{\Sigma_{ij}\}$ is called the *macroscopic stress field.* It is defined by $\Sigma =< \sigma^1 >$. The strain field $E = e_x(u^0)$ is called the *macroscopic strain field* and satisfies

$$E =< e_x(u^0) + e_y(u^1) >$$

It can be proved that the homogenized coefficients $q_{ij}^{k\ell}$ satisfy

$$\begin{cases} q_{ij}^{k\ell} = q_{k\ell}^{ij} (= q_{ijk\ell}) \\ q_{ij}^{k\ell} s_{ij} s_{k\ell} \geq \alpha_1 s_{ij} s_{ij}, \quad \forall s_{ij} = s_{ji} \text{ some } \alpha_1 > 0 \end{cases}$$

This shows that $(q_{ij}^{k\ell})$ are reasonable elastic coefficients and that the macroscopic scale problem (27)(28) has a unique solution.

This homogenized system describes the macroscopic deformation and stress fields of the system subject to external forces and boundary conditions. It is the effective parameter representation of the medium. Since we are interested in the microscopic stresses which characterize the fiber matrix interface, we must push the analysis a little further to reveal this information.

2.2.3 Microscopic Fields – Localization

The stress field $\sigma^1(x,y)$ is the first term of the asymptotic expansion (11) of the stress field $\sigma^\epsilon(x)$ solution of the initial exact problem. The field $\sigma^1(x,y)$ is called the microscopic stress field. If we imagine that at each point $x \in \Omega$, there is a small ϵY period with its composite structure, i.e., a "cell" of the overall structure, then $\sigma^1(x,y)$ gives, for x kept fixed in Ω, a stress field in this period.

It can be shown that $\sigma^\epsilon(x) - \sigma^1(x, x/\epsilon)$ tends to zero when ϵ tends to zero.[7] This proves that $\sigma^1(x, x/\epsilon)$ is a good approximation to $\sigma^\epsilon(x)$ when ϵ is small. The microscopic stress field $\sigma^1(x,y), y = x/\epsilon$ can be calculated as follows:

(i) First, we obtain the six $\chi^{k\ell}(y)$ vector fields on Y, each one associated with tensor $\tau^{k\ell} = \tau^{\ell k}$. These six vector-fields are solutions of problem (22) which is an elasticity problem on the large scale (period) Y.

(ii) From the vector fields $\chi^{k\ell}$ we get the homogenized coefficients $q_{ij}^{k\ell}$ by formula (25).

[7] In the $L^1(\Omega)$ norm; that is, $\lim_{\epsilon\to 0} \int_\Omega |\sigma^\epsilon(x) - \sigma^1(x, x/\epsilon)| dx = 0$.

(iii) We solve the macroscopic scale, homogenized elastic problem (27)(28) on Ω for the macroscopic stress field $\Sigma(x)$ and the macroscopic strain field $e_x(u^0) = E(x)$, for $x \in \Omega$.

(iv) The localization procedure: Using formula (23), we can calculate $\sigma^1(x,y)$. For x fixed in Ω, this stress field on Y shows how the macroscopic stress $\Sigma(x) = <\sigma^1(x,y)>$ is localized in an ϵY–period (cell) at the point $x \in \Omega$.

This procedure can be rigorously justified in the sense that it can be shown that when ϵ tends to zero, the stress field $\sigma^\epsilon(x)$ tends to $\Sigma(x)$. Nevertheless, $\sigma^1(x, x/\epsilon)$ is a better approximation to $\sigma^\epsilon(x)$ than $\Sigma(x)$.[8] The macroscopic stress field $\Sigma(x)$ is just a mean value while $\sigma^1(x, x/\epsilon)$ takes into account the fine periodic structure of the composite material.

2.3 Comments

These results demonstrate the effectiveness of homogenization theory in computing the mechanical characteristics of composite materials. Validity of the results depends on the assumptions made on the shapes and layout of fibers (especially periodicity). Of course, a method which permits treatment of random fiber directions would be able to capture the actual physical situation more precisely. However, the undeniable advantage of this method derives from its capability to supply complete sets of parameter values, which are mutually coherent. Comparisons with experimental evidence and other techniques such as the Halpin–Tsai formulas indicate that the estimates based on the homogenization theory are more accurate than those based on other methods [7,15,16].

An important challenge is to move from the ability to characterize the material properties of composites to characterizing the macroscopic behavior of structures fabricated from these advanced materials. There has been very little work on this subject, and it is important that the software models provide a basis for the development of CAD tools for treatment of these issues.[9]

[8] Precisely, the norm $L^1(\Omega)$ convergence implies that $\sigma^\epsilon(x) - \sigma^1(x, x/\epsilon)$ tends to zero for almost every point in Ω, while the (weak) $L^2(\Omega)$ convergence governing the approach of σ^ϵ to Σ does not.

[9] See [83] for a general discussion of the impact of composites on design of high performance

The basic analytical method can be extended to treat elementary structures fabricated from composites. In the next section we discuss the treatment of laminates formed from fiber–reinforced composites. The analysis of such systems has been a problem in the past, see the discussion in [71]. The homogenization method can readily treat laminates with a large number of layers; a problem that has presented difficulties for other methods. More complex structures can also be treated by iteratively applying the method. For example, in treating tubular members made from composites one can compute the material properties of the composite using the homogenization procedure, evaluate the stiffness and bending properties of the tube based on this, and then refine the model by examining the distribution of microstresses in the wall of the tube as a function of fiber alignment and geometry. The deformations of a sleeve coupling element may be similarly treated.

More complex molded structures are a different matter, since the macroscopic geometry of the element will have to be considered even in the local analysis. That is the "shape" of the region Ω will be very complex for certain molded structures; and it will have to be treated explicitly in the homogenization analysis. One possible approach is to use an iterated finite element procedure in which finite elements in the large scale representation of the complex region Ω are themselves represented as "composite elements" which are are in turn treated as a collection of "cells" whose compliance properties are evaluated using the homogenization procedure. The behavior of the overall molded structure would then be derived by a "superposition" of the individual behaviors of each of its "composite elements." Implementation of this procedure would be a very challenging problem in numerical (finite element) analysis. The simplicity and similarity of the "composite elements" would have to be exploited in setting up the analysis. If properly formulated, the analysis of the "composite elements" could be done in parallel.

---

systems. See the papers [45,51,72] for discussions of design objectives for laminated fibrous composite plates and related structures . The homogenization method is applied to design in [48].

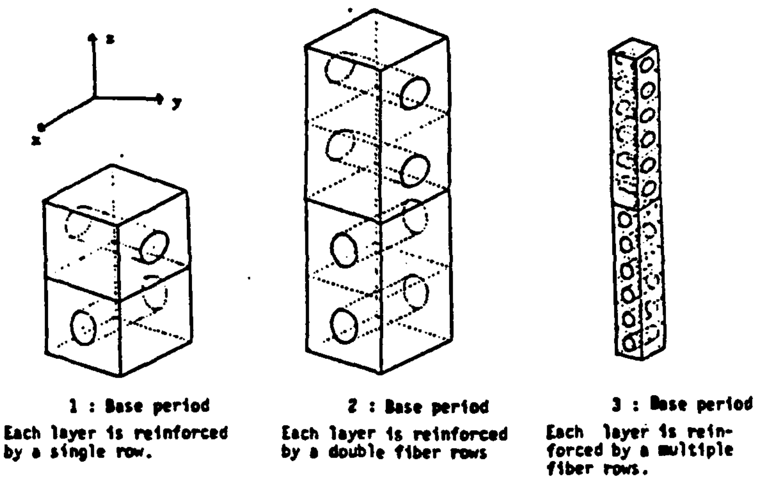

Figure 4: Multiple layer reinforced composites.

3 Numerical Evaluation of Effective Moduli and Microscopic Stress Fields

3.1 Application of the Method to a Cross Ply Laminate

To illustrate use of the homogenization method in a concrete case, consider a cross ply lamination consisting of orthotropic layers with an alternating orientation of 90° between the layers. We assume that the x and the y axes are parallel to the fiber reinforcement in the odd and the even numbered layers respectively. All the odd layers are identical. As are the even layers. To compare the results, we shall consider three types of layers: (See Figure 4.)

Example 1: Each layer is reinforced by a single fiber row.

Example 2: Each layer is reinforced by a double fiber row.

Example 3: Each layer is reinforced by multiple fiber rows.

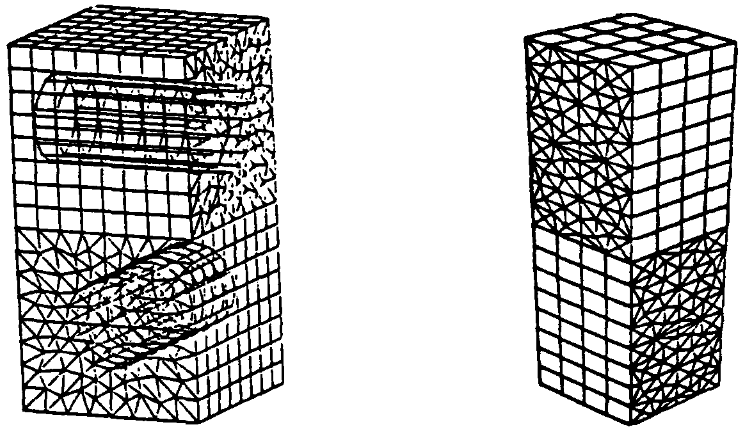

Figure 5: Triangular finite element mesh of the cross section of a period Y.

The first two examples are solved by using the homogenization procedure in three dimensions. The last example is solved in two steps by using a two-dimensional analysis:

(i) Homogenization of each layer reinforced by fibers running in the same direction. The problem defined by (22) is bidimensional.

(ii) Homogenization of the cross ply lamination using the computed results for each layer given by the first step.

The numerical results are obtained by using a finite element code. See Figure 5.

3.2 Three Dimensional Homogenization of the Cross Ply Laminate

To obtain the homogenized moduli $q_{ij}^{k\ell}$ (25), it is necessary, to first compute the functions $\chi^{k\ell}$ which are solutions of elliptic boundary value problems on the basic period (22). To compute the functions $\chi^{k\ell}$ by a finite element code, the system (22) is reformulated in variational form

$$\begin{cases} \chi^{k\ell} \in V & = \{\underline{v} = (v_1, v_2, v_3), \underline{v} \in \{H^1(Y)\}^3, \underline{v} \text{ is } Y-\text{periodic} \\ a_y(\chi^{k\ell}, \underline{v}) & = \int_Y a_{ijk\ell}(y) e_{ij}(v)\,dy, \quad \forall v \in V \end{cases} \tag{30}$$

where

$$a_y(\underline{u},\underline{v}) = \int_Y a_{ijk\ell}(y)e_{i\ell}(\underline{u})e_{ij}(\underline{v})dy$$

The last integral in (30) can be written in terms of the surface load:

$$\int_Y a_{ijk\ell}(y)e_{ij}(\underline{v})dy = \int_\Gamma \underline{F}^{k\ell} \cdot \underline{v}d\gamma$$

with

$$\begin{array}{lll} F_1^{11} = [a_{11\ell 1}]n_\ell & F_2^{11} = [a_{11\ell 2}]n_\ell & F_3^{11} = [a_{11\ell 3}]n_\ell \\ F_1^{22} = [a_{22\ell 1}]n_\ell & F_2^{22} = [a_{22\ell 2}]n_\ell & F_3^{22} = [a_{22\ell 3}]n_\ell \\ F_1^{33} = [a_{33\ell 1}]n_\ell & F_2^{33} = [a_{33\ell 2}]n_\ell & F_3^{33} = [a_{33\ell 3}]n_\ell \\ F_1^{23} = [a_{23\ell 1}]n_\ell & F_2^{23} = [a_{23\ell 2}]n_\ell & F_3^{23} = [a_{11\ell 3}]n_\ell \\ F_1^{13} = [a_{13\ell 1}]n_\ell & F_2^{13} = [a_{13\ell 2}]n_\ell & F_3^{13} = [a_{11\ell 3}]n_\ell \\ F_1^{12} = [a_{12\ell 1}]n_\ell & F_2^{12} = [a_{12\ell 2}]n_\ell & F_3^{12} = [a_{12\ell 3}]n_\ell \end{array}$$

where $\underline{n} = (n_1, n_2, n_3)$ is the outward unit normal to the interface of the components (fiber-resin) and where the bracket $[\cdot]$ denotes the jump of a function across the interface.

Given numerical representations of the functions $\chi^{k\ell}$, the homogenized coefficients $q_{ijk\ell}$ of the composite system are the mean value, over a period Y of the corresponding $a_{ijk\ell}$ altered by a corrector term (25) depending on the $\chi^{k\ell}$, explicitly:

$$\begin{cases} q_{ijk\ell} = < a_{ijk\ell}(y) > -q^*_{ijk\ell} \\ q^*_{ijk\ell} = \frac{1}{|Y|} \int_Y a_{ijpq} \frac{\partial \chi_p^{k\ell}}{\partial y_q} dy \end{cases}$$

3.3 Two-Dimensional Homogenization of the Cross Ply Laminate

As stated previously, the Example 3 is solved in two steps:

Step 1: *Homogenization of a composite reinforced by fibers running in the same direction.* See Figure 6.

Calculation of the homogenized coefficients $q_{ijk\ell}$ requires resolution of (22). In the present case the coefficients $a_{ijk\ell}(y)$ are independent of y_3. Consequently, the

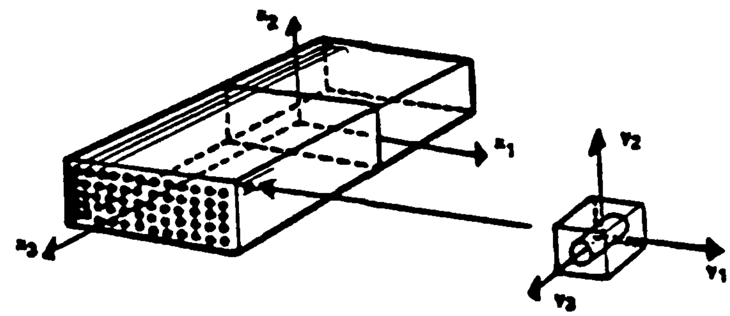

Figure 6: Composite reinforced by fibers running in the same direction

fields $\chi^{k\ell}(y)$ are also independent of y_3. In (22)(30) those indices referring to $\partial/\partial y_3$ give zero contribution. This makes the computation of $\chi^{ij}(y)$ a two dimensional problem. In addition, we have:

$$\chi^{k\ell}(y) = \chi^{k\ell}(y_1, y_2) = [\chi_1^{k\ell}(y_1, y_2), \chi_2^{k\ell}(y_1, y_2), 0]$$

These functions are therefore solutions of a plane strain elasticity problem. And,

$$\chi^{k\ell}(y) = \chi^{k\ell}(y_1, y_2) = [0, 0, \chi_3^{k\ell}(y_1, y_2)] \text{ for } (k, \ell) = [(1,3), (2,3)]$$

These two functions for solutions of a scalar problem in $\Re^2$. (Details of this reduction are given in [7].)

Step 2: Homogenization of the cross ply lamination. See Figure 7.

Using the homogenized moduli of each layer (from step one), the homogenization formulas are considerably simplified. The problem (22) is reduced to a system of differential equations which may be solved explicitly.

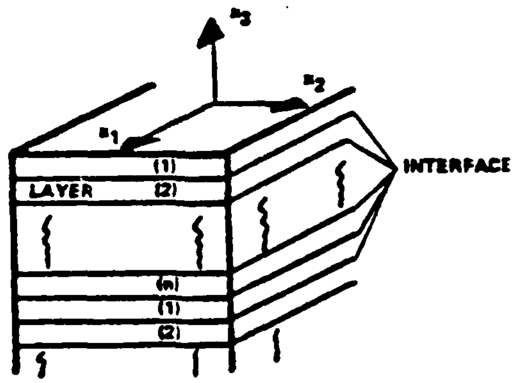

Figure 7: Multiple layers: Each layer possesses a plane of elastic symmetry normal to the x_3 axis.

3.4 Sample numerical results

3.4.1 Effective Parameter Models

The results obtained (from a finite element code) for the two first examples are compared with those obtained for the last example 3 in the tables which follow: Each component is assumed elastic, homogeneous, and isotropic with:

$$\begin{array}{lll} E_f = 84,000 \text{ MPa} & \nu_f = .22 & \text{for the fiber} \\ E_r = 4,000 \text{ MPa} & \nu_r = .34 & \text{for the resin} \end{array}$$

Results for 3 impregnations of resin (36%, 50%, 65%) are shown in Tables 1,2,3.

3.4.2 Numerical Results for the Microscopic Stress-Field

In the previous paragraph, we have shown that we get the homogenized moduli q_{ijkl} from the six vector fields $\chi^{kl}(y)$. We can then solve the homogenized elastic problem (27)(28), on Ω which gives the macroscopic stress field $\Sigma(x)$, for $x \in \Omega$. The computations of the microscopic stress-field and stress forces at the interface

Example	E1 (MPa)	E2 (MPa)	E3 (MPa)	G23 (MPa)	G13 (MPa)	G12 (MPa)	ν_{23}	ν_{13}	ν_{12}
1	37,700	37,700	18,900	5,600	5,600	6,775	.27	.27	.135
2	37,780	37,780	19,850	5,570	5,570	6,670	.259	.259	.137
3	37,750	37,750	20,614	5,298	5,298	6,304	.24	.24	.138

Table 1: Comparative table for 36% resin by volume.

Example	E1 (MPa)	E2 (MPa)	E3 (MPa)	G23 (MPa)	G13 (MPa)	G12 (MPa)	ν_{23}	ν_{13}	ν_{12}
1	28,340	28,340	12,996	3,800	3,800	4,300	.32	.32	.122
2	28,400	28,400	13,280	3,780	3,780	4,276	.308	.308	.124
3	28,801	28,801	13,563	3,598	3,598	4,168	.297	.297	.124

Table 2: Comparative table for 50% resin by volume.

Example	E1 (MPa)	E2 (MPa)	E3 (MPa)	G23 (MPa)	G13 (MPa)	G12 (MPa)	ν_{23}	ν_{13}	ν_{12}
1	20,500	20,500	9,471	2,880	2,880	3,076	.33	.35	.126
2	20,560	20,560	9,565	2,850	2,850	3,057	.35	.35	.128
3	20,237	20,237	9,243	2,657	2,657	2,910	.35	.35	.126

Table 3: Comparative table for 65% resin by volume.

between fiber and resin, are particularly important because they can initiate cracks and delaminations. The localization procedure allows an easy computation of these microscopic stress-field and stress forces.

Numerical results for an unidirectionally fiber-reinforced composite subjected to a shearing stress-field normal to the direction of the fibers are shown in Figure 8. Other cases can be treated in a similar manner. The stress forces $\sigma \cdot n$ at the interface and the components of microscopic stress field are plotted. The density of lines plotted indicate the level of microscopic stress concentration.

The elastic moduli of the components are:

Fiber: E = 84000 Mpa	$\nu = 0.22$
Resin: E = 4000 Mpa	$\nu = 0.34$

The corresponding homogenized moduli for 50% resin impregnations are

$$
\begin{array}{lllllllll}
E1 & = & 10141 Mpa & \nu_{32} & = & 0.287 & G_{32} & = & 3106 \\
E2 & = & 9685 Mpa & \nu_{31} & = & 0.281 & G_{31} & = & 3386 \\
E3 & = & 35655 Mpa & \nu_{12} & = & 0.353 & G_{12} & = & 2606
\end{array}
$$

4 Numerical Results for Effective Moduli and Microscopic Stress Fields

In this section we present transcripts of interactive sessions with the MeMCAP software system. Computation of the effective moduli is treated in the next subsection. Evaluation of the microscopic distribution of stresses at the fiber–matrix interface is treated in the last subsection. In Listings 1 and 2 at the end of the report we provide more extensive examples of the performance of the program modules.

4.1 Effective Moduli for Various Fiber–Matrix Geometries

In the session which follows the homogenized compliance tensor defining the relationship between the stress and strain tensors, $\{\epsilon\} = [E]\{\sigma\}$, is computed for

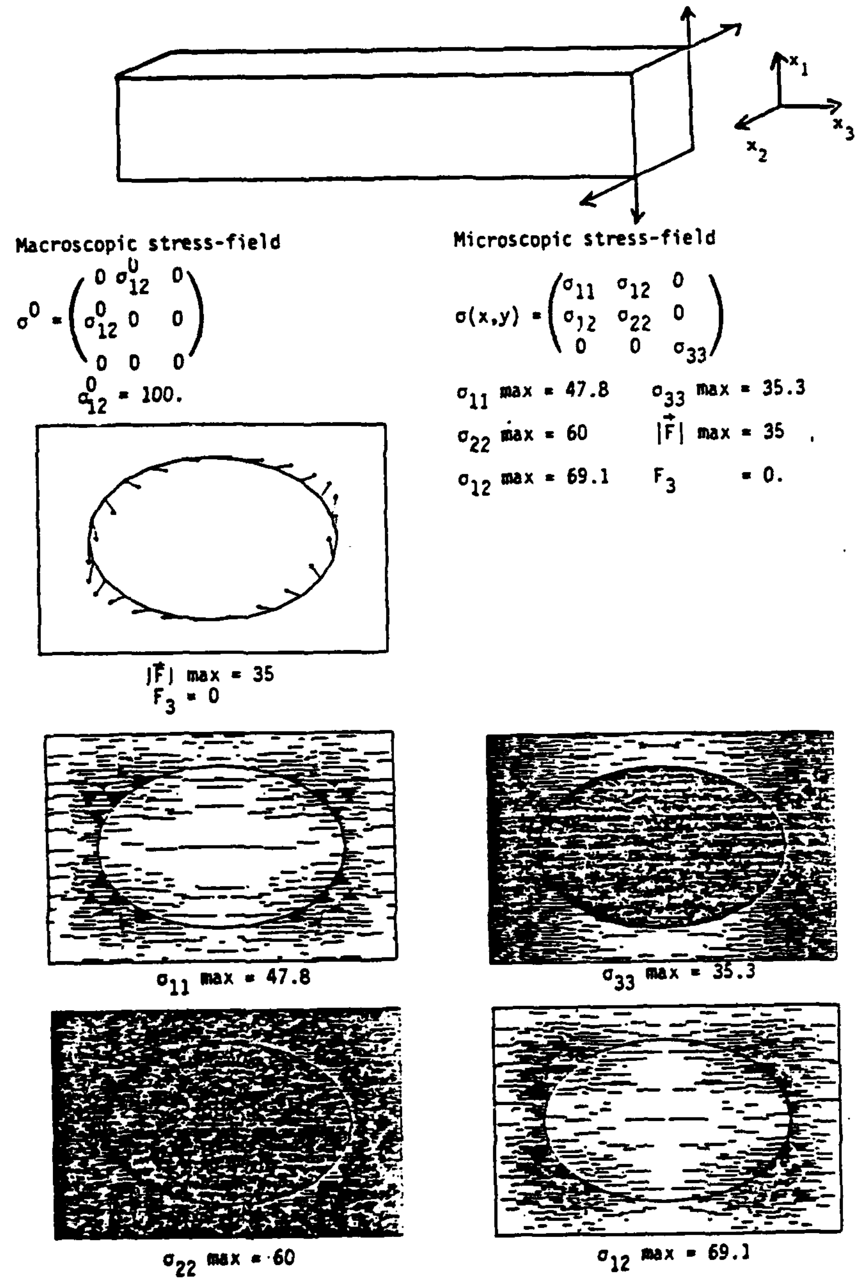

Figure 8: Microstress field for shearing load normal to direction of fibers.

sample fiber types and orientations. Specifically, we computed the system

$$\begin{bmatrix} e_{11} \\ e_{22} \\ e_{33} \\ e_{23} \\ e_{13} \\ e_{12} \end{bmatrix} = \begin{bmatrix} \frac{1}{E_1} & -\frac{\nu_{12}}{E_1} & -\frac{\nu_{13}}{E_1} & 0 & 0 & 0 \\ -\frac{\nu_{12}}{E_1} & \frac{1}{E_2} & -\frac{\nu_{23}}{E_2} & 0 & 0 & 0 \\ -\frac{\nu_{13}}{E_1} & -\frac{\nu_{23}}{E_2} & \frac{1}{E_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{2G_{23}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{2G_{13}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{2G_{12}} \end{bmatrix} \cdot \begin{bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{23} \\ \sigma_{13} \\ \sigma_{12} \end{bmatrix}$$

Here $E_i, i = 1,2,3$ are Young's moduli for the fiber (composite) directions $x_i, i = 1,2,3$; $G_{ij}, i,j = 1,2,3$ are the fiber (composite) shear moduli, and $\nu_{ij}, i,j = 1,2,3$ are the fiber (composite) Poisson coefficients.

The homogenization methodology was used to compute the effective parameters. As shown in the previous section, this requires solution of an elliptic partial differential equation in a typical "cell" of the (periodic) structure. This solution was found by a finite element procedure. The solution is then used in an averaging procedure which produces the effective parameters.

4.1.1 Design of the MeMCAP Supervisor

We have developed a menu-driven supervisor program called the "Metal-Matrix Composites Analysis Program (`MeMCAP`)" to facillitate interaction with the numerical programs which compute the effective parameters of the "homogenized" representation of fiber reinforced materials.[10] An overview of this software is shown in Figure 9.

The flow diagram of the menu-oriented supervisor module is shown in Figure 10.

Currently, the software allows the user to (i) get help, (ii) set up a problem via a simple screen-oriented editor and (iii) submit a batch job to compute the effective parameters of the current problem. The numerical results are saved in a `.LOG` file.

[10] In fact, most of the data used in the computations here is for resin based composites. We have not used metal matrix data (in this unrestricted document) in part to avoid issues related to the ITAR.

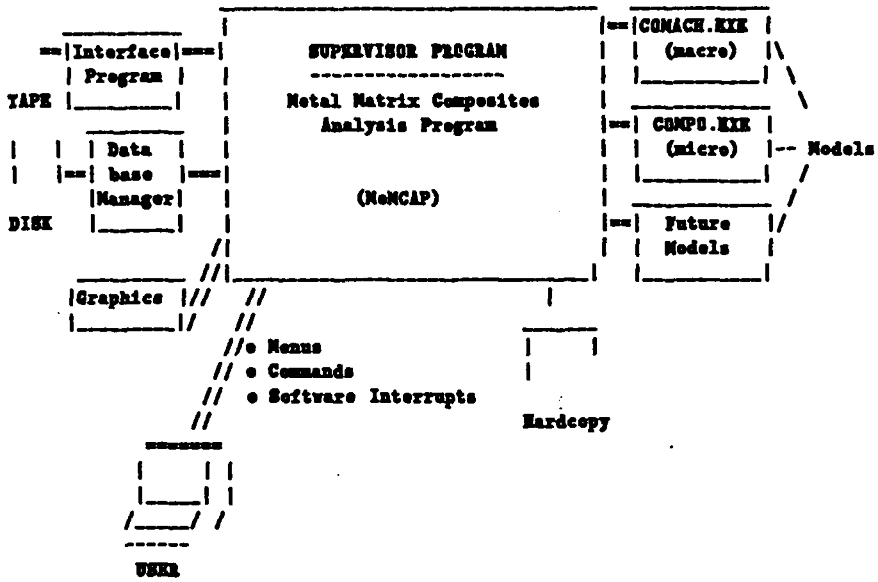

Figure 9: Overview of MeMCAP software system.

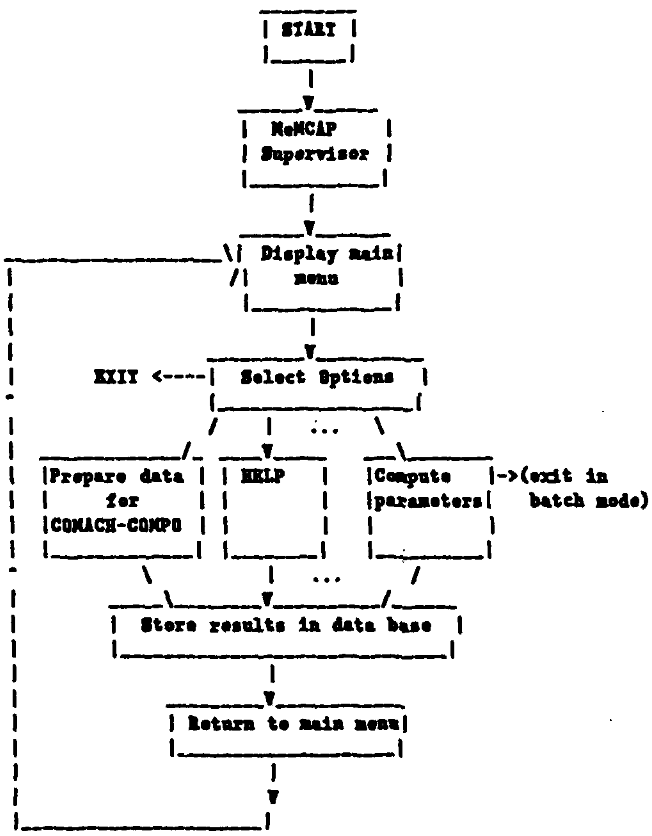

Figure 10: Flow diagram of MeMCAP Supervisor.

The system is written in Fortran. It assumes the user has a VT100 terminal or compatible. The system is just a prototype; we plan significant enhancements in further work.

4.1.2 Sample Session with the MeMCAP Interface

The output from a sample run is shown below. Each page corresponds to a display screen on the user's terminal.

```
$ run memcap

                         WELCOME
                           TO
                *********************************
                *          M e M C A P          *
                *    Metal Matrix Composites    *
                *       Analysis Program        *
                *********************************

   PROTOTYPE PROGRAM FOR COMPUTING THE EFFECTIVE PARAMETERS
                OF METAL MATRIX COMPOSITES

                       DEVELOPED BY

              SYSTEMS ENGINEERING INCORPORATED
               7833 WALKER DRIVE, SUITE 308
                    GREENBELT, MD 20770

 *** PRESS THE "RETURN" KEY TO CONTINUE ***
```

```
                MAIN MENU                      ABBREVIATIONS
                ---------                      -------------

            1  HELP (BRIEF DESCRIPTION OF SOME ITEMS) - (HELP)
            2  PREPARE DATA FILE FOR COMPUTATIONS    -- (PREP)
            3  COMPUTE EFFECTIVE PARAMETERS          -- (COMP)
            4  ..........................................
            5  ..........................................
            6  ..........................................
            0  QUIT

            PLEASE ENTER YOUR SELECTION NUMBER:
MAIN>1
```

```
HELP    - Help available on the following topics:

          HELP  - displays this list.     HISTORY - history of this project.

          NEWS  - info. on revisions.     COMP - compute eff. parameters

          PREP - preparation of data file.

          SUMMARY - general description.



---------------------------------------------------------------------

1. TO SEE A DIRECTORY OF HELP ITEMS, TYPE "HELP".
2. OR ENTER NAME OF ITEM FOR WHICH YOU WANT HELP.
3. WHEN FINISHED, TYPE "EXIT" OR "QUIT".
---------------------------------------------------------------------

EXIT
```

```
              MAIN MENU                  ABBREVIATIONS
              ---------                  -------------

          1  HELP (BRIEF DESCRIPTION OF SOME ITEMS) - (HELP)
          2  PREPARE DATA FILE FOR COMPUTATIONS    -- (PREP)
          3  COMPUTE EFFECTIVE PARAMETERS          -- (COMP)
          4  ..........................................
          5  ..........................................
          6  ..........................................
          0  QUIT

          PLEASE ENTER YOUR SELECTION NUMBER:
MAIN>2
```

```
ITEM          DESCRIPTION            TYP          CURRENT VALUE

  1. Project title                    C Metal Matrix Composites Analysis

  2. Project/Contract Number          C test

  3. Generic Name                     C TEST

  4. IFIB                             I 1

     Fiber type:

     1 = Isotropic Circular Fiber

     2 = Orthotropic Circular Fiber

     3 = Isotropic Kidney Fiber

     4 = Orthotropic Kidney Fiber

     5 = Isotropic Staggered Fiber

TYP: C=CHARACTER, I=INTEGER, L=LOGICAL, R=REAL, X=COMPLEX

-----------------------------------------------------------------

1. TO CHANGE CURRENT ITEM, ENTER NEW VALUE, THEN HIT RETURN.
2. OR ENTER "#" FOLLOWED BY ITEM NUMBER YOU WANT TO CHANGE.
3. TO WRITE BACK FILE AND EXIT, TYPE "EXIT". ELSE "QUIT".
-----------------------------------------------------------------

QUIT
```

```
                    MAIN MENU                    ABBREVIATIONS
                    ---------                    -------------

          1  HELP (BRIEF DESCRIPTION OF SOME ITEMS) - (HELP)
          2  PREPARE DATA FILE FOR COMPUTATIONS    -- (PREP)
          3  COMPUTE EFFECTIVE PARAMETERS          -- (COMP)
          4  ...........................................
          5  ...........................................
          6  ...........................................
          0  QUIT

          PLEASE ENTER YOUR SELECTION NUMBER:
MAIN>3

SUBMITTING BATCH JOB, LOGFILE IS "COMACH.LOG"
Job COMACH (queue SYS$BATCH, entry 1098) started on SYS$BATCH
```

The results for this case are shown below (i.e., the following is a listing of the .LOG file created by the module COMACH.EXE):

```
$RUN SEI$USR:[CRANE]COMACH

 GENERIC NAME :
IFIB ? ( = 1 ISOTROPIC CIRCULAR FIBER)
       ( = 2 ORTHOTROPIC CIRCULAR FIBER)
       ( = 3 ISOTROPIC KIDNEY FIBER)
       ( = 4 ORTHOTROPIC KIDNEY FIBER)
       ( = 5 ISOTROPIC STAGGERED FIBER)
       ( = 6 ORTHOTROPIC STAGGERED FIBER)
       ( = 7 HEXAGONAL CELL ISOTROPIC KIDNEY FIBER)
       ( = 8 HEXAGONAL CELL ORTHOTROPIC KIDNEY FIBER)
          1
IOPT = ?  IF = 1 PROVIDE THE SIDE RATIO ( SIDE_//_Y / SIDE_//_X )
                      AND THE RESIN RATIO
          IF = 2 PROVIDE THE SIDE RATIO , THE RESIN RATIO,
                        HDIST ( MESH  DENSITY PARAMETER )
          1
SIDE RATIO ? (REAL)
      1.0000000
RESIN RATIO ? ( > 0.2348894 )
      0.5000000
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC FIBER)
  84000.0000000
      0.2200000
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC RESIN)
   4000.0000000
      0.3400000
```

```
THE FIBERS  ARE  PARALLEL AT  X1
********************************


NOTATICNS     E1,E2,E3: YOUNG  MODULI  FIBER (COMPOSITE) DIRECTIONS X1,X2,X3
*********     GIJ      : FIBER ( COMPOSITE )  SHEAR  MODULI
              NU(IJ)   : FIBER ( COMPOSITE )  POISSON COEFFICIENT
              ER       : RESIN  YOUNG  MODULUS
              NUR      : RESIN  POISSON  COEFFICIENT
              NEL      : NUMBER OF ELEMENTS
              NOE      : NUMBER OF NODES
              TXR      : RESIN IMPREGNATED RATIO IN VOLUME


****************************************************************************

*             ISOTROPIC CIRCULAR FIBER        *ISOTROPIC RESIN*   MESH      *

*...........................................*...............*.............*

* E1 =  84000. . G12 = 34426. . NU12 = 0.220 *  ER   =  4000. * NEL =  176  *

* E2 =  84000. . G13 = 34426. . NU13 = 0.220 *                * NOE =  105  *

* E3 =  84000. . G23 = 34426. . NU23 = 0.220 *  NUR =  0.340 * TXR = .5082 *

****************************************************************************
```

HOMOGENIZED ELASTIC TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.4625E+05	0.5296E+04	0.5297E+04	-0.7273E-13	0.0000E+00	0.0000E+00
0.5296E+04	0.1468E+05	0.4762E+04	-0.3214E-12	0.0000E+00	0.0000E+00
0.5297E+04	0.4762E+04	0.1468E+05	-0.8976E-13	0.0000E+00	0.0000E+00
-0.7273E-13	-0.3214E-12	-0.8976E-13	0.3113E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4077E+04	0.9916E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.9916E-04	0.4077E+04

HOMOGENIZED COMPLIANCE TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.2306E-04	-0.6283E-05	-0.6283E-05	-0.2910E-21	0.0000E+00	0.0000E+00
-0.6283E-05	0.7786E-04	-0.2299E-04	0.7228E-20	0.0000E+00	0.0000E+00
-0.6283E-05	-0.2299E-04	0.7785E-04	-0.2754E-21	0.0000E+00	0.0000E+00
-0.2910E-21	0.7228E-20	-0.2754E-21	0.3212E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2453E-03	-0.5967E-11
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.5967E-11	0.2453E-03

E1 = 0.433659D+05	E2 = 0.128441D+05	E3 = 0.128445D+05
NU23 = 0.295292D+00	NU12 = 0.272460D+00	NU13 = 0.272458D+00
G23 = 0.311300D+04	G12 = 0.407657D+04	G13 = 0.407662D+04

ROTATION 45 DEGREES AROUND X1

HOMOGENIZED COMPLIANCE TENSOR (BISECTING DIRECTIONS)

1 1	2 2	3 3	2 3	1 3	1 2
0.2306E-04	-0.6283E-05	-0.6283E-05	0.6650E-10	0.0000E+00	0.0000E+00
-0.6283E-05	0.1077E-03	-0.5288E-04	-0.1208E-08	0.0000E+00	0.0000E+00
-0.6283E-05	-0.5288E-04	0.1077E-03	-0.1208E-08	0.0000E+00	0.0000E+00
0.6650E-10	-0.1208E-08	-0.1208E-08	0.2017E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2453E-03	-0.1574E-08
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.1574E-08	0.2453E-03

E1 = 0.433659D+05	E2 = 0.928151D+04	E3 = 0.928151D+04
NU23 = 0.490768D+00	NU12 = 0.272459D+00	NU13 = 0.272459D+00
G23 = 0.495805D+04	G12 = 0.407659D+04	G13 = 0.407659D+04

```
FORTRAN STOP

  CRANE      job terminated at 11-MAY-1987 14:34:58.43

  Accounting information:
  Buffered I/O count:             98     Peak working set size:  1354
  Direct I/O count:              164     Peak page file size:    3151
  Page faults:                  1363     Mounted volumes:           0
  Charged CPU time:      0 00:01:07.49   Elapsed time:      0 00:01:20.34
```

The program was run on SEI's VAX 11/750, which has a floating point accelerator and 6 Megbytes of core memory. Listing 1 at the end of the report contains analyses of eight different fiber–matrix geometries to illustrate the range of options available in this module of the system.

4.2 Evaluation of the Microscopic Stress Fields

The MeMCAP software includes a module (COMPO.EXE) for the evaluation of microscopic stress distributions in a typical cell of the composite material. The system is setup to handle cases in which:

1. The fibers are run in the same direction and are periodically distributed with a (i) staggered or (ii) aligned rectangular base period.
2. The fiber material is (i) isotropic or (ii) orthrotropic.
3. The matrix material is (i) isotropic, (ii) orthrotropic, or (iii) incompressible.
4. The fibers are (i) circular or (ii) elliptical.[11]
5. The microscopic stress field is computed for six main (stress) loadings: (i) $S_{11} = 1, S_{ij} = 0, i \neq j$, (ii) $S_{22} = 1, S_{ij} = 0, i \neq j$, (iii) $S_{33} = 1, S_{ij} = 0, i \neq j$, (iv) $S_{23} = 1, S_{ij} = 0, i \neq j$, (v) $S_{13} = 1, S_{ij} = 0, i \neq j$, (vi) $S_{12} = 1, S_{ij} = 0, i \neq j$.

The finite element mesh is automatically generated given the description of the cell geometry and the fiber–matrix impregnation ratio.[12] A minimum ratio is provided for each fiber shape and geometry.

The software requires the following input data:

1. Output device: terminal or filename.
2. Fiber characteristics: aligned or staggered; isotropic or orthotropic; spacing of fibers in x and in y; and shape – circular or ellipse (a, b, n).
3. Fiber–matrix impregnation ratio.
4. Elasticity characteristics: Matrix – isotropic (E, ν); orthotropic (E_i, G_{ij}, ν_{ij}); or incompressible (E, ν); and Fiber – isotropic (E, ν) or orthotropic (E_i, G_{ij}, ν_{ij}).

[11] Actually, a generalised elliptical shape is permitted $(x/a)^n + (y/b)^n = 1$.

[12] An optional parameter (HDIST) can be used to refine the mesh near the boundary.

The software produces the following output information either on the user's terminal or into a file, as directed by the user:

1. A summary of the input data.
2. The homogenized elasticity tensor.
3. The homogenized compliance tensor.
4. Equivalent elastic moduli.
5. A summary of the finite element mesh including number of elements and number of nodes. For each element the program provides: number, material number (1 for fiber, 2 for matrix), node number, and node coordinates. This informationn serves to localize the microstresses in the fiber–matrix system.
6. For each stress loading the microscopic stress field by element number (in the mesh).
7. The stress force at the interface between matrix and fiber in terms of element number, node coordinates, and stress force components.

The results of a typical interactive session with the software are given in Listing 2.[13] The listing of microscopic stress distributions by mesh element is useful in anticipating design objectives and limitations. It is also possible to have the results displayed in a graphical format. Figures 11,12,13 show the microstress distribution in a typical cell in response to various loadings. The colors correspond to various stress levels.

[13] To save space, we omit details of the interaction with the system through the supervisor interface.

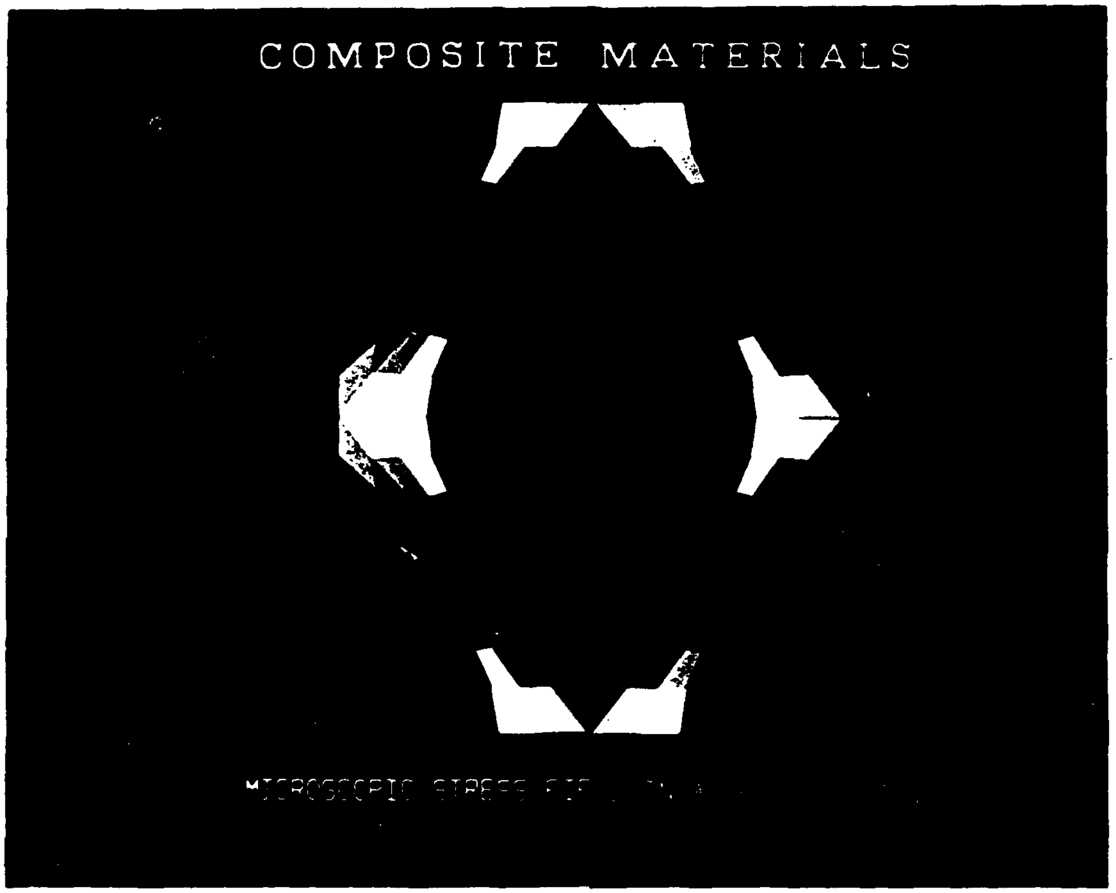

Figure 11: Microstress distribution in a typical cell.

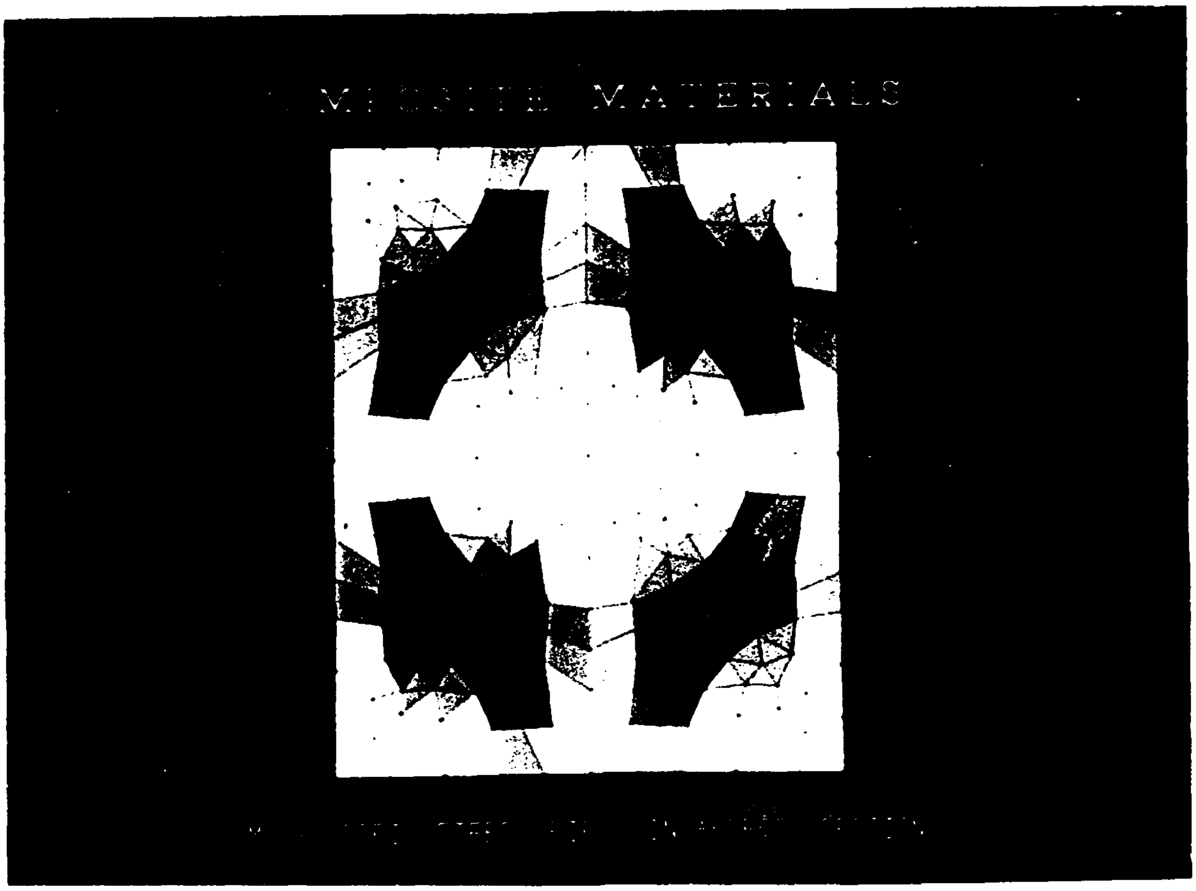

Figure 12: Microstress distribution in a typical cell (alternate loading).

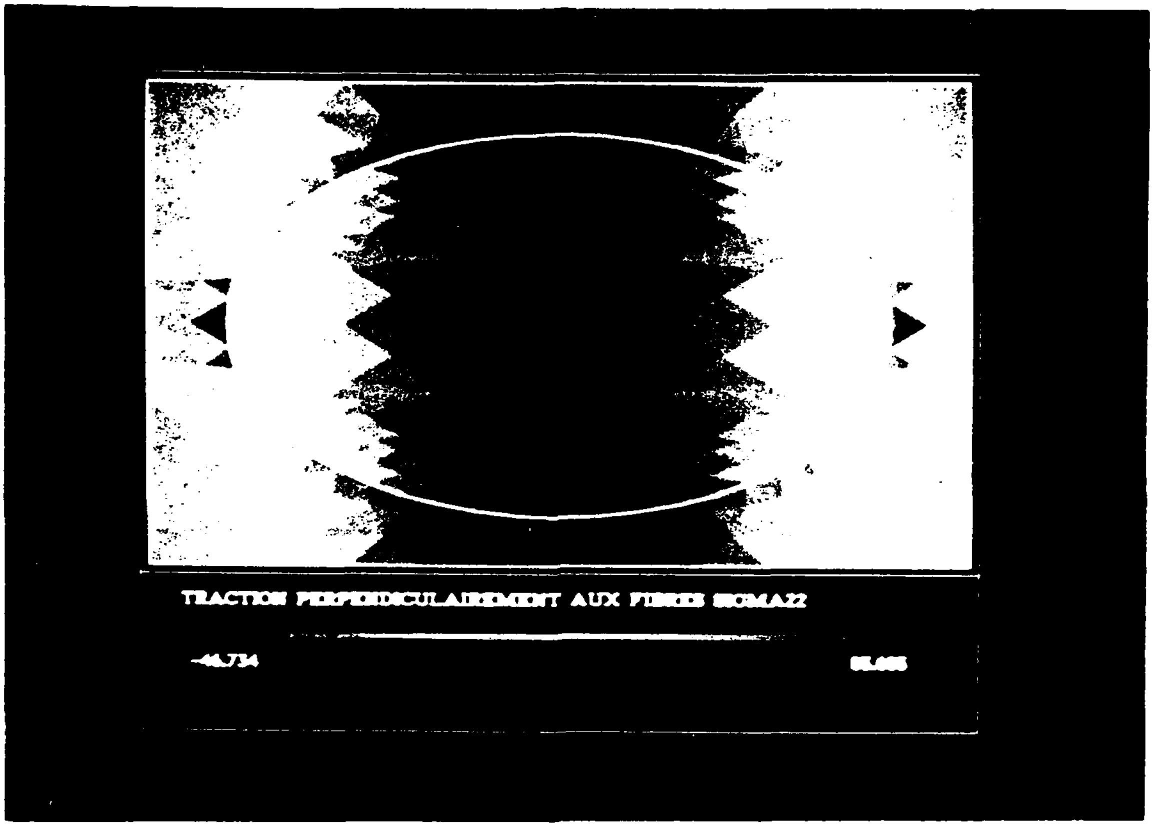

Figure 13: Microstress distribution in a typical cell (alternate geometry).

5 Conclusions and Further Research and Development

5.1 Accomplishments of the Project

The objective of our Phase I research program was to demonstrate the feasibility of the homogenization method to compute the effective parameter representations of fiber reinforced composites. We have produced analytical results and a software system which meet this objective. It is important to stress that the analytical methods are systematic and consistent.

5.2 Further Phase II Research and Development

Several enhancements to the software are possible which would make it a more complete CAD system for investigation and design of composite materials and structures constructed from such materials.

1. As we have already indicated, it would be relatively straight–forward to add enhancements to treat the viscoelastic and thermal properties of (periodic) composites (in the linear regime).
2. Similarly, it is possible to adapt the methods to treat plasticity in composites – a particularly important consideration in the analysis and design of *metal matrix composites.*
3. It is possible to adapt the analytical methods to treat both short–fiber and particulate reinforced composites; however, in these cases it is important to be able to treat systems with a random infrastructure.
4. Systems with a random infrastructure can be treated using homogenization. The general theory has been worked out [59]. Extensive applications have been given both for nonlinear problems [10] and for systems with a discrete infrastructure (heat propagation on a random lattice) [50]. In related research

SEI is developing numerical methods for the treatment of homogenization problems for random structures.[14]

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Listing 1: Computation of Effective Moduli

```
RUN COMACH

 GENERIC NAME :
F1
IFIB ? ( = 1 ISOTROPIC CIRCULAR FIBER)
       ( = 2 ORTHOTROPIC CIRCULAR FIBER)
       ( = 3 ISOTROPIC KIDNEY FIBER)
       ( = 4 ORTHOTROPIC KIDNEY FIBER)
       ( = 5 ISOTROPIC STAGGERED FIBER)
       ( = 6 ORTHOTROPIC STAGGERED FIBER)
       ( = 7 HEXAGONAL CELL ISOTROPIC KIDNEY FIBER)
       ( = 8 HEXAGONAL CELL ORTHOTROPIC KIDNEY FIBER)
1
IOPT = ?  IF = 1 PROVIDE THE SIDE RATIO ( SIDE_//_Y / SIDE_//_X )
                     AND THE RESIN RATIO
          IF = 2 PROVIDE THE SIDE RATIO , THE RESIN RATIO,
                     HDIST ( MESH  DENSITY PARAMETER )
1
SIDE RATIO ? (REAL)
1
RESIN RATIO ? ( > 0.2348394 )
.5
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC FIBER)
84000. .22
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC RESIN)
4000. .34

THE FIBERS  ARE  PARALLEL AT  X1
********************************

NOTATIONS     E1,E2,E3: YOUNG  MODULI  FIBER (COMPOSITE) DIRECTIONS X1,X2,X3
*********     GIJ     : FIBER ( COMPOSITE )  SHEAR  MODULI
              NU(IJ)  : FIBER ( COMPOSITE )  POISSON COEFFICIENT
              ER      : RESIN  YOUNG  MODULUS
              NUR     : RESIN  POISSON  COEFFICIENT
              NEL     : NUMBER OF ELEMENTS
              NOE     : NUMBER OF NODES
              TXR     : RESIN IMPREGNATED RATIO IN VOLUME

***************************************************************************
*           ISOTROPIC CIRCULAR FIBER          *ISOTROPIC RESIN*   MESH       *
*.............................................*...............*.............*
* E1 =  84000. . G12 = 34426. . NU12 = 0.220 *  ER  =  4000. * NEL =  176  *
* E2 =  84000. . G13 = 34426. . NU13 = 0.220 *               * NOE =  105  *
* E3 =  84000. . G23 = 34426. . NU23 = 0.220 *  NUR =  0.340 * TXR = .5062 *
***************************************************************************

***************************************************************************
*                     HOMOGENIZED ELASTIC  TENSOR                           *
*.........................................................................*
*     1 1         2 2         3 3         2 3         1 3         1 2      *
```

0.4625E+05	0.5296E+04	0.5297E+04	-0.7273E-13	0.0000E+00	0.0000E+00
0.5296E+04	0.1468E+05	0.4762E+04	-0.3214E-12	0.0000E+00	0.0000E+00
0.5297E+04	0.4762E+04	0.1468E+05	-0.8976E-13	0.0000E+00	0.0000E+00
-0.7273E-13	-0.3214E-12	-0.8976E-13	0.3113E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4077E+04	0.9916E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.9916E-04	0.4077E+04

HOMOGENIZED COMPLIANCE TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.2306E-04	-0.6283E-05	-0.6283E-05	-0.2910E-21	0.0000E+00	0.0000E+00
-0.6283E-05	0.7786E-04	-0.2299E-04	0.7228E-20	0.0000E+00	0.0000E+00
-0.6283E-05	-0.2299E-04	0.7785E-04	-0.2754E-21	0.0000E+00	0.0000E+00
-0.2910E-21	0.7228E-20	-0.2754E-21	0.3212E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2453E-03	-0.5967E-11
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.5967E-11	0.2453E-03

E1 =	0.433659D+05	E2 =	0.128441D+05	E3 =	0.128445D+05
NU23 =	0.295292D+00	NU12 =	0.272460D+00	NU13 =	0.272458D+00
G23 =	0.311300D+04	G12 =	0.407657D+04	G13 =	0.407662D+04

ROTATION 45 DEGREES AROUND X1

HOMOGENIZED COMPLIANCE TENSOR (BISECTING DIRECTIONS)

1 1	2 2	3 3	2 3	1 3	1 2
0.2306E-04	-0.6283E-05	-0.6283E-05	0.6650E-10	0.0000E+00	0.0000E+00
-0.6283E-05	0.1077E-03	-0.5288E-04	-0.1208E-08	0.0000E+00	0.0000E+00
-0.6283E-05	-0.5288E-04	0.1077E-03	-0.1208E-08	0.0000E+00	0.0000E+00
0.6650E-10	-0.1208E-08	-0.1208E-08	0.2017E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2453E-03	-0.1574E-08
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.1574E-08	0.2453E-03

E1 =	0.433659D+05	E2 =	0.928151D+04	E3 =	0.928151D+04
NU23 =	0.490768D+00	NU12 =	0.272459D+00	NU13 =	0.272459D+00
G23 =	0.495805D+04	G12 =	0.407659D+04	G13 =	0.407659D+04

GENERIC NAME :

```
IFIB ? ( = 1 ISOTROPIC CIRCULAR FIBER)
       ( = 2 ORTHOTROPIC CIRCULAR FIBER)
       ( = 3 ISOTROPIC KIDNEY FIBER)
       ( = 4 ORTHOTROPIC KIDNEY FIBER)
       ( = 5 ISOTROPIC STAGGERED FIBER)
       ( = 6 ORTHOTROPIC STAGGERED FIBER)
       ( = 7 HEXAGONAL CELL ISOTROPIC KIDNEY FIBER)
       ( = 8 HEXAGONAL CELL ORTHOTROPIC KIDNEY FIBER)
2
IOPT = ?  IF = 1 PROVIDE THE SIDE RATIO ( SIDE_//_Y / SIDE_//_X )
                      AND THE RESIN RATIO
          IF = 2 PROVIDE THE SIDE RATIO , THE RESIN RATIO,
                      HDIST ( MESH  DENSITY PARAMETER )
1
SIDE RATIC ? (REAL)
1
RESIN RATIO ? ( > 0.2348894 )
.5
E1 , E2 , E3 = ? (ORTHOTROPIC FIBERS // A X1)
380000. 14500. 14500.
G12 , G13 , G23 = ? (ORTHOTROPIC FIBERS // A X1)
38000. 38000. 20000.
NU12 , NU13 , NU23 = ? (ORTHOTROPIC FIBERS // A X1)
.22 .22 .25
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC RESIN)
3520. .38

THE FIBERS  ARE  PARALLEL AT  X1
*********************************

NOTATIONS     E1,E2,E3: YOUNG  MODULI  FIBER (COMPOSITE) DIRECTIONS X1,X2,X3
*********     GIJ     : FIBER ( COMPOSITE )  SHEAR  MODULI
              NU(IJ)  : FIBER ( COMPOSITE )  POISSON COEFFICIENT
              ER      : RESIN  YOUNG  MODULUS
              NUR     : RESIN  POISSON  COEFFICIENT
              NEL     : NUMBER OF ELEMENTS
              NOE     : NUMBER OF NODES
              TXR     : RESIN IMPREGNATED RATIO IN VOLUME

*****************************************************************************
*             ORTHOTROPIC CIRCULAR FIBER        *ISOTROPIC RESIN*   MESH      *
*...............................................*...............*............*
* E1 = 380000. . G12 = 38000. . NU12 = 0.220 *  ER  =  3520. * NEL =  176  *
* E2 =  14500. . G13 = 38000. . NU13 = 0.220 *                * NOE =  105  *
* E3 =  14500. . G23 = 20000. . NU23 = 0.250 *  NUR =  0.380 * TXR = .5082 *
*****************************************************************************

*****************************************************************************
*                       HOMOGENIZED ELASTIC  TENSOR                          *
*...........................................................................*
*     1 1         2 2         3 3         2 3         1 3         1 2       *
```

0.1912E+06	0.4126E+04	0.4126E+04	-0.2165E-14	0.0000E+00	0.0000E+00
0.4126E+04	0.9683E+04	0.4199E+04	0.3317E-13	0.0000E+00	0.0000E+00
0.4126E+04	0.4199E+04	0.9684E+04	-0.2809E-13	0.0000E+00	0.0000E+00
-0.2165E-14	0.3317E-13	-0.2809E-13	0.2600E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3570E+04	0.1208E-02
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1208E-02	0.3570E+04

HOMOGENIZED COMPLIANCE TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.5299E-05	-0.1575E-05	-0.1575E-05	0.7495E-23	0.0000E+00	0.0000E+00
-0.1575E-05	0.1277E-03	-0.5469E-04	-0.2221E-20	0.0000E+00	0.0000E+00
-0.1575E-05	-0.5469E-04	0.1277E-03	0.2076E-20	0.0000E+00	0.0000E+00
0.7495E-23	-0.2221E-20	0.2076E-20	0.3847E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2801E-03	-0.9472E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.9472E-10	0.2801E-03

E1 = 0.188710D+06	E2 = 0.783349D+04	E3 = 0.783375D+04
NU23 = 0.428386D+00	NU12 = 0.297201D+00	NU13 = 0.297186D+00
G23 = 0.259957D+04	G12 = 0.357042D+04	G13 = 0.357046D+04

ROTATICN 45 DEGREES AROUND X1

HOMOGENIZED COMPLIANCE TENSOR (BISECTING DIRECTICNS)

1 1	2 2	3 3	2 3	1 3	1 2
0.5299E-05	-0.1575E-05	-0.1575E-05	0.8287E-10	0.0000E+00	0.0000E+00
-0.1575E-05	0.1327E-03	-0.5969E-04	-0.2108E-08	0.0000E+00	0.0000E+00
-0.1575E-05	-0.5969E-04	0.1327E-03	-0.2108E-08	0.0000E+00	0.0000E+00
0.8287E-10	-0.2108E-08	-0.2108E-08	0.3647E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2801E-03	-0.1869E-08
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.1869E-08	0.2801E-03

E1 = 0.188710D+06	E2 = 0.753840D+04	E3 = 0.753840D+04
NU23 = 0.449934D+00	NU12 = 0.297193D+00	NU13 = 0.297193D+00
G23 = 0.274211D+04	G12 = 0.357044D+04	G13 = 0.357044D+04

GENERIC NAME :
T3

```
IFIB ? ( = 1 ISOTROPIC CIRCULAR FIBER)
       ( = 2 ORTHOTROPIC CIRCULAR FIBER)
       ( = 3 ISOTROPIC KIDNEY FIBER)
       ( = 4 ORTHOTROPIC KIDNEY FIBER)
       ( = 5 ISOTROPIC STAGGERED FIBER)
       ( = 6 ORTHOTROPIC STAGGERED FIBER)
       ( = 7 HEXAGONAL CELL ISOTROPIC KIDNEY FIBER)
       ( = 8 HEXAGONAL CELL ORTHOTROPIC KIDNEY FIBER)
3
IOPT ? (IF = 1 PROVIDE RATIO  : IMPREGNATED  RESIN
       (IF = 2 PROVIDE RATIO  : IMPREGNATED  RESIN
                       HDIST  : MESH DENSITY PARAMETER )
IOPT = ?
1
RATIO = ? ( TXMIN = 0.3545 )
.5
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC FIBER)
84000. .22
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC RESIN)
4000. .34

THE FIBERS  ARE  PARALLEL AT  X1
*********************************

NOTATIONS      E1,E2,E3: YOUNG  MODULI  FIBER (COMPOSITE) DIRECTIONS X1,X2,X3
*********      GIJ     : FIBER ( COMPOSITE )  SHEAR  MODULI
               NU(IJ)  : FIBER ( COMPOSITE )  POISSON COEFFICIENT
               ER      : RESIN  YOUNG  MODULUS
               NUR     : RESIN  POISSON  COEFFICIENT
               NEL     : NUMBER OF ELEMENTS
               NOE     : NUMBER OF NODES
               TXR     : RESIN IMPREGNATED RATIO IN VOLUME

***************************************************************************
*        ISOTROPIC KIDNEY (0.29) FIBER       *ISOTROPIC RESIN*   MESH     *
*.........................................*...............*.............*
* E1 =  84000. . G12 = 34426. . NU12 = 0.220 *  ER  =  4000. * NEL =  310  *
* E2 =  84000. . G13 = 34426. . NU13 = 0.220 *               * NOE =  172  *
* E3 =  84000. . G23 = 34426. . NU23 = 0.220 *  NUR =  0.340 * TXR = .5041 *
***************************************************************************

***************************************************************************
*                       HOMOGENIZED ELASTIC  TENSOR                        *
*.........................................................................*
*      1 1          2 2          3 3          2 3          1 3          1 2       *
*   0.4673E+05   0.5663E+04   0.5663E+04   0.3834E+03   0.0000E+00   0.0000E+00   *
*   0.5663E+04   0.1463E+05   0.6551E+04   0.9122E+03   0.0000E+00   0.0000E+00   *
*   0.5663E+04   0.6551E+04   0.1463E+05   0.9122E+03   0.0000E+00   0.0000E+00   *
*   0.3834E+03   0.9122E+03   0.9122E+03   0.4503E+04   0.0000E+00   0.0000E+00   *
*   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.4965E+04   0.1195E+04   *
*   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.1195E+04   0.4965E+04   *
```

```
*****************************************************************************
*****************************************************************************
*                     HOMOGENIZED COMPLIANCE  TENSOR
*...........................................................................
*        1 1          2 2          3 3          2 3          1 3          1 2
*   0.2288E-04  -0.6141E-05  -0.6141E-05   0.5396E-06   0.0000E+00   0.0000E+00
*  -0.6141E-05   0.8754E-04  -0.3620E-04  -0.9878E-05   0.0000E+00   0.0000E+00
*  -0.6141E-05  -0.3620E-04   0.8754E-04  -0.9877E-05   0.0000E+00   0.0000E+00
*   0.5396E-06  -0.9878E-05  -0.9877E-05   0.2260E-03   0.0000E+00   0.0000E+00
*   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.2138E-03  -0.5146E-04
*   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00  -0.5146E-04   0.2138E-03
*****************************************************************************


                               ORTHOTROPY AXIS
                               ***************

*****************************************************************************
*           HOMOGENIZED  COMPLIANCE  TENSOR  (BISECTING DIRECTIONS)         *
*...........................................................................*
*        1 1          2 2          3 3          2 3          1 3          1 2   *
*   0.2268E-04  -0.5871E-05  -0.6411E-05   0.1930E-12   0.0000E+00   0.0000E+00 *
*  -0.5871E-05   0.7230E-04  -0.3083E-04   0.3689E-10   0.0000E+00   0.0000E+00 *
*  -0.6411E-05  -0.3083E-04   0.9205E-04  -0.4395E-10   0.0000E+00   0.0000E+00 *
*   0.1930E-12   0.3689E-10  -0.4395E-10   0.2475E-03   0.0000E+00   0.0000E+00 *
*   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.2652E-03  -0.3174E-10 *
*   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00  -0.3174E-10   0.1623E-03 *
*****************************************************************************

*****************************************************************************
*                                                                           *
*  E1    =  0.436986D+05      E2    =  0.138318D+05      E3    =  0.108634D+05  *
*                                                                           *
*  NU23  =  0.426484D+00      NU12  =  0.256556D+00      NU13  =  0.280135D+00  *
*                                                                           *
*  G23   =  0.404050D+04      G12   =  0.616080D+04      G13   =  0.377019D+04  *
*                                                                           *
*****************************************************************************
 GENERIC NAME :
T4
IFIB ? ( = 1 ISOTROPIC CIRCULAR FIBER)
       ( = 2 ORTHOTROPIC CIRCULAR FIBER)
       ( = 3 ISOTROPIC KIDNEY FIBER)
       ( = 4 ORTHOTROPIC KIDNEY FIBER)
       ( = 5 ISOTROPIC STAGGERED FIBER)
       ( = 6 ORTHOTROPIC STAGGERED FIBER)
       ( = 7 HEXAGONAL CELL ISOTROPIC KIDNEY FIBER)
       ( = 8 HEXAGONAL CELL ORTHOTROPIC KIDNEY FIBER)
4
IOPT ? (IF = 1 PROVIDE RATIO  : IMPREGNATED  RESIN
       (IF = 2 PROVIDE RATIO  : IMPREGNATED  RESIN
                       HDIST  : MESH DENSITY PARAMETER )
IOPT = ?
1
RATIO = ? ( TXMIN = 0.3545 )
.5
```

```
E1 , E2 , E3 = ? (ORTHOTROPIC FIBERS // A X1)
380000. 14500. 14500.
G12 , G13 , G23 = ? (ORTHOTROPIC FIBERS // A X1)
38000. 38000. 20000.
NU12 , NU13 , NU23 = ? (ORTHOTROPIC FIBERS // A X1)
.22 .22 .25
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC RESIN)
3520. .38
```

THE FIBERS ARE PARALLEL AT X1

```
NOTATIONS      E1,E2,E3: YOUNG MODULI FIBER (COMPOSITE) DIRECTIONS X1,X2,X3
*********      GIJ     : FIBER ( COMPOSITE ) SHEAR MODULI
               NU(IJ)  : FIBER ( COMPOSITE ) POISSON COEFFICIENT
               ER      : RESIN YOUNG MODULUS
               NUR     : RESIN POISSON COEFFICIENT
               NEL     : NUMBER OF ELEMENTS
               NOE     : NUMBER OF NODES
               TXR     : RESIN IMPREGNATED RATIO IN VOLUME
```

KIDNEY FIBER (0.29) ORTHOTROPIC			ISOTROPIC RESIN	MESH
E1 = 380000.	G12 = 38000.	NU12 = 0.220	ER = 3520.	NEL = 310
E2 = 14500.	G13 = 38000.	NU13 = 0.220		NOE = 172
E3 = 14500.	G23 = 20000.	NU23 = 0.250	NUR = 0.380	TXR = .5041

HOMOGENIZED ELASTIC TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.1927E+06	0.4129E+04	0.4129E+04	0.1017E+02	0.0000E+00	0.0000E+00
0.4129E+04	0.9432E+04	0.4565E+04	0.1899E+03	0.0000E+00	0.0000E+00
0.4129E+04	0.4565E+04	0.9432E+04	0.1899E+03	0.0000E+00	0.0000E+00
0.1017E+02	0.1899E+03	0.1899E+03	0.3536E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4438E+04	0.1145E+04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1145E+04	0.4438E+04

HOMOGENIZED COMPLIANCE TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.5256E-05	-0.1553E-05	-0.1553E-05	0.1517E-06	0.0000E+00	0.0000E+00
-0.1553E-05	0.1390E-03	-0.6651E-04	-0.3888E-05	0.0000E+00	0.0000E+00
-0.1553E-05	-0.6651E-04	0.1390E-03	-0.3888E-05	0.0000E+00	0.0000E+00
0.1517E-06	-0.3888E-05	-0.3888E-05	0.2532E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2414E-03	-0.6225E-04
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.6225E-04	0.2414E-03

```
****************************************************************************

                           ORTHOTROPY AXIS
                           ***************

****************************************************************************
*         HOMOGENIZED  COMPLIANCE  TENSOR  (BISECTING DIRECTIONS)          *
*--------------------------------------------------------------------------*
*      1 1          2 2          3 3          2 3          1 3          1 2 *
*  0.5256E-05 -0.1477E-05 -0.1628E-05 -0.1109E-15  0.0000E+00  0.0000E+00  *
* -0.1477E-05  0.1032E-03 -0.3458E-04 -0.1007E-12  0.0000E+00  0.0000E+00  *
* -0.1628E-05 -0.3458E-04  0.1109E-03  0.1064E-12  0.0000E+00  0.0000E+00  *
* -0.1109E-15 -0.1007E-12  0.1064E-12  0.4110E-03  0.0000E+00  0.0000E+00  *
*  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.3036E-03  0.4099E-12  *
*  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.4099E-12  0.1791E-03  *
****************************************************************************

****************************************************************************
*                                                                          *
*  E1   =  0.190243D+06     E2   =  0.969418D+04     E3   =  0.901470D+04  *
*                                                                          *
*  NU23 =  0.335190D+00     NU12 =  0.280952D+00     NU13 =  0.309803D+00  *
*                                                                          *
*  G23  =  0.243337D+04     G12  =  0.558297D+04     G13  =  0.329352D+04  *
*                                                                          *
****************************************************************************
 GENERIC NAME :
T5
IFIB ? ( = 1 ISOTROPIC CIRCULAR FIBER)
       ( = 2 ORTHOTROPIC CIRCULAR FIBER)
       ( = 3 ISOTROPIC KIDNEY FIBER)
       ( = 4 ORTHOTROPIC KIDNEY FIBER)
       ( = 5 ISOTROPIC STAGGERED FIBER)
       ( = 6 ORTHOTROPIC STAGGERED FIBER)
       ( = 7 HEXAGONAL CELL ISOTROPIC KIDNEY FIBER)
       ( = 8 HEXAGONAL CELL ORTHOTROPIC KIDNEY FIBER)
5
IOPT ? (IF = 1 PROVIDE : LENGTH RATIO
                       : RESIN INTEGRATED RATIO
       (IF = 2 PROVIDE : L , RATIO AND HDIST : DENSITY
                         MESH PARAMETER        )
1
L ?
1.73
RATIO ? ( >0.199 )
.5
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC FIBER)
84000. .22
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC RESIN)
4000. .34

THE FIBERS  ARE  PARALLEL AT  X1
********************************
```

NOTATIONS		
*********	E1, E2, E3	: YOUNG MODULI FIBER (COMPOSITE) DIRECTIONS X1, X2, X3
	GIJ	: FIBER (COMPOSITE) SHEAR MODULI
	NU(IJ)	: FIBER (COMPOSITE) POISSON COEFFICIENT
	ER	: RESIN YOUNG MODULUS
	NUR	: RESIN POISSON COEFFICIENT
	NEL	: NUMBER OF ELEMENTS
	NOE	: NUMBER OF NODES
	TXR	: RESIN IMPREGNATED RATIO IN VOLUME

STAGGERED CIRCLE FIBER(1.73) ISOTROPIC			ISOTROPIC RESIN	MESH
E1 = 84000.	G12 = 34426.	NU12 = 0.220	ER = 4000.	NEL = 224
E2 = 84000.	G13 = 34426.	NU13 = 0.220		NOE = 135
E3 = 84000.	G23 = 34426.	NU23 = 0.220	NUR = 0.340	TXR = .5129

HOMOGENIZED ELASTIC TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.4586E+05	0.5246E+04	0.5259E+04	-0.8083E-13	0.0000E+00	0.0000E+00
0.5246E+04	0.1352E+05	0.5675E+04	-0.1687E-12	0.0000E+00	0.0000E+00
0.5259E+04	0.5675E+04	0.1359E+05	-0.2499E-12	0.0000E+00	0.0000E+00
-0.8083E-13	-0.1687E-12	-0.2499E-12	0.3883E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4005E+04	0.5464E-03
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.5464E-03	0.4016E+04

HOMOGENIZED COMPLIANCE TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.2326E-04	-0.6359E-05	-0.6343E-05	-0.2005E-21	0.0000E+00	0.0000E+00
-0.6359E-05	0.9140E-04	-0.3572E-04	0.1539E-20	0.0000E+00	0.0000E+00
-0.6348E-05	-0.3572E-04	0.9098E-04	0.4172E-20	0.0000E+00	0.0000E+00
-0.2005E-21	0.1539E-20	0.4172E-20	0.2576E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2497E-03	-0.3397E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.3397E-10	0.2490E-03

E1 = 0.429907D+05	E2 = 0.109414D+05	E3 = 0.109914D+05
NU23 = 0.390776D+00	NU12 = 0.273366D+00	NU13 = 0.272890D+00
G23 = 0.388259D+04	G12 = 0.401618D+04	G13 = 0.400490D+04

```
                    ROTATION 45 DEGREES  AROUND  X1
                    *********************************

**************************************************************************************
*          HOMOGENIZED  COMPLIANCE  TENSOR  (BISECTING DIRECTIONS)                 *
*----------------------------------------------------------------------------------*
*      1 1          2 2          3 3          2 3          1 3          1 2        *
*   0.2326E-04  -0.6353E-05  -0.6353E-05   0.1152E-07   0.0000E+00   0.0000E+00   *
*  -0.6353E-05   0.9213E-04  -0.3665E-04  -0.2076E-06   0.0000E+00   0.0000E+00   *
*  -0.6353E-05  -0.3665E-04   0.9213E-04  -0.2076E-06   0.0000E+00   0.0000E+00   *
*   0.1152E-07  -0.2076E-06  -0.2076E-06   0.2538E-03   0.0000E+00   0.0000E+00   *
*   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.2493E-03   0.3508E-06   *
*   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.3508E-06   0.2493E-03   *
**************************************************************************************

**************************************************************************************
*                                                                                  *
*   E1   =  0.429907D+05      E2   =  0.108546D+05      E3   =  0.108546D+05      *
*                                                                                  *
*   NU23 =  0.397661D+00      NU12 =  0.273138D+00      NU13 =  0.273138D+00      *
*                                                                                  *
*   G23  =  0.394000D+04      G12  =  0.401053D+04      G13  =  0.401053D+04      *
*                                                                                  *
**************************************************************************************
 GENERIC NAME :
T6
IFIB ? ( = 1 ISOTROPIC CIRCULAR FIBER)
       ( = 2 ORTHOTROPIC CIRCULAR FIBER)
       ( = 3 ISOTROPIC KIDNEY FIBER)
       ( = 4 ORTHOTROPIC KIDNEY FIBER)
       ( = 5 ISOTROPIC STAGGERED FIBER)
       ( = 6 ORTHOTROPIC STAGGERED FIBER)
       ( = 7 HEXAGONAL CELL ISOTROPIC KIDNEY FIBER)
       ( = 8 HEXAGONAL CELL ORTHOTROPIC KIDNEY FIBER)
6
IOPT ? (IF = 1 PROVIDE : LENGTH RATIO
                       : RESIN INTEGRATED RATIO
       (IF = 2 PROVIDE : L , RATIO AND HDIST : DENSITY
                         MESH PARAMETER        )
2
L ?
1
RATIO ? ( >0.342 )
.5
HDIST ? ( < 0.15)
.1
E1 , E2 , E3 = ? (ORTHOTROPIC FIBERS // A X1)
380000. 14500. 14500.
G12 , G13 , G23 = ? (ORTHOTROPIC FIBERS // A X1)
38000. 38000. 20000.
NU12 , NU13 , NU23 = ? (ORTHOTROPIC FIBERS // A X1)
.22 .22 .25
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC RESIN)
3520. .38

THE FIBERS  ARE  PARALLEL AT  X1
*********************************
```

NOTATIONS
****

E1,E2,E3	:	YOUNG MODULI FIBER (COMPOSITE) DIRECTIONS X1,X2,X3
GIJ	:	FIBER (COMPOSITE) SHEAR MODULI
NU(IJ)	:	FIBER (COMPOSITE) POISSON COEFFICIENT
ER	:	RESIN YOUNG MODULUS
NUR	:	RESIN POISSON COEFFICIENT
NEL	:	NUMBER OF ELEMENTS
NOE	:	NUMBER OF NODES
TXR	:	RESIN IMPREGNATED RATIO IN VOLUME

STAGGERED CIRCLE FIBER(1.00) ORTHOTROPIC *ISOTROPIC RESIN* MAILLAGE

E1 = 380000.	G12 = 38000.	NU12 = 0.220	ER = 3520.	NEL = 416
E2 = 14500.	G13 = 38000.	NU13 = 0.220		NOE = 233
E3 = 14500.	G23 = 20000.	NU23 = 0.250	NUR = 0.380	TXR = .5083

HOMOGENIZED ELASTIC TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.1911E+06	0.4126E+04	0.4126E+04	0.1870E-13	0.0000E+00	0.0000E+00
0.4126E+04	0.9131E+04	0.4751E+04	0.3713E-13	0.0000E+00	0.0000E+00
0.4126E+04	0.4751E+04	0.9132E+04	-0.6529E-14	0.0000E+00	0.0000E+00
0.1870E-13	0.3713E-13	-0.6529E-14	0.4125E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3562E+04	0.1212E-03
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1212E-03	0.3562E+04

HOMOGENIZED COMPLIANCE TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.5300E-05	-0.1575E-05	-0.1575E-05	-0.1235E-22	0.0000E+00	0.0000E+00
-0.1575E-05	0.1506E-03	-0.7765E-04	-0.1472E-20	0.0000E+00	0.0000E+00
-0.1575E-05	-0.7765E-04	0.1506E-03	0.9445E-21	0.0000E+00	0.0000E+00
-0.1235E-22	-0.1472E-20	0.9445E-21	0.2424E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2807E-03	-0.9550E-11
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.9550E-11	0.2807E-03

E1 = 0.188674D+06	E2 = 0.663894D+04	E3 = 0.663952D+04
NU23 = 0.515522D+00	NU12 = 0.297217D+00	NU13 = 0.297169D+00
G23 = 0.412510D+04	G12 = 0.356195D+04	G13 = 0.356230D+04

ROTATION 45 DEGREES AROUND X1
****

HOMOGENIZED COMPLIANCE TENSOR (BISECTING DIRECTIONS)

1 1	2 2	3 3	2 3	1 3	1 2
0.5300E-05	-0.1575E-05	-0.1575E-05	0.2549E-09	0.0000E+00	0.0000E+00
-0.1575E-05	0.9709E-04	-0.2412E-04	-0.6483E-08	0.0000E+00	0.0000E+00
-0.1575E-05	-0.2412E-04	0.9709E-04	-0.6483E-08	0.0000E+00	0.0000E+00
0.2549E-09	-0.6483E-08	-0.6483E-08	0.4565E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2807E-03	-0.1381E-07
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.1381E-07	0.2807E-03

E1 =	0.168674D+06	E2 =	0.102998D+05	E3 =	0.102998D+05
NU23 =	0.248435D+00	NU12 =	0.297193D+00	NU13 =	0.297193D+00
G23 =	0.219038D+04	G12 =	0.356213D+04	G13 =	0.356213D+04

```
GENERIC NAME :
T7
IFIB ? ( = 1 ISOTROPIC CIRCULAR FIBER)
       ( = 2 ORTHOTROPIC CIRCULAR FIBER)
       ( = 3 ISOTROPIC KIDNEY FIBER)
       ( = 4 ORTHOTROPIC KIDNEY FIBER)
       ( = 5 ISOTROPIC STAGGERED FIBER)
       ( = 6 ORTHOTROPIC STAGGERED FIBER)
       ( = 7 HEXAGONAL CELL ISOTROPIC KIDNEY FIBER)
       ( = 8 HEXAGONAL CELL ORTHOTROPIC KIDNEY FIBER)
7
RATIO = ? ( TXMIN = 0.3961 )
.5
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC FIBER)
84000. .22
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC RESIN)
4000. .34
```

THE FIBERS ARE PARALLEL AT X1
****

NOTATIONS
****

E1,E2,E3	:	YOUNG MODULI FIBER (COMPOSITE) DIRECTIONS X1,X2,X3
GIJ	:	FIBER (COMPOSITE) SHEAR MODULI
NU(IJ)	:	FIBER (COMPOSITE) POISSON COEFFICIENT
ER	:	RESIN YOUNG MODULUS
NUR	:	RESIN POISSON COEFFICIENT
NEL	:	NUMBER OF ELEMENTS
NOE	:	NUMBER OF NODES
TXR	:	RESIN IMPREGNATED RATIO IN VOLUME

HEXAGONAL CELL	FIBER	ISOTROPIC KIDNEY	ISOTROPIC RESIN	MESH
E1 = 84000.	G12 = 34426.	NU12 = 0.220	ER = 4000.	NEL = 498
E2 = 84000.	G13 = 34426.	NU13 = 0.220		NOE = 274
E3 = 84000.	G23 = 34426.	NU23 = 0.220	NUR = 0.340	TXR = .5089

HOMOGENIZED ELASTIC TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.4630E+05	0.5548E+04	0.5548E+04	0.3217E-04	0.0000E+00	0.0000E+00
0.5548E+04	0.1449E+05	0.6149E+04	0.6630E-04	0.0000E+00	0.0000E+00
0.5548E+04	0.6149E+04	0.1449E+05	0.9458E-04	0.0000E+00	0.0000E+00
0.3217E-04	0.6630E-04	0.9453E-04	0.4170E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4507E+04	0.1544E-02
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1544E-02	0.4507E+04

HOMOGENIZED COMPLIANCE TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.2309E-04	-0.6207E-05	-0.6207E-05	0.6134E-13	0.0000E+00	0.0000E+00
-0.6207E-05	0.8585E-04	-0.3406E-04	-0.5446E-12	0.0000E+00	0.0000E+00
-0.6207E-05	-0.3406E-04	0.8585E-04	-0.1358E-11	0.0000E+00	0.0000E+00
0.6134E-13	-0.5446E-12	-0.1353E-11	0.2398E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2219E-03	-0.7602E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.7602E-10	0.2219E-03

E1 = 0.433152D+05	E2 = 0.116479D+05	E3 = 0.116479D+05
NU23 = 0.396722D+00	NU12 = 0.268842D+00	NU13 = 0.268842D+00
G23 = 0.416972D+04	G12 = 0.450693D+04	G13 = 0.450693D+04

ROTATION 45 DEGREES AROUND X1

HOMOGENIZED COMPLIANCE TENSOR (BISECTING DIRECTIONS)

1 1	2 2	3 3	2 3	1 3	1 2

```
*  0.2309E-04 -0.6207E-05 -0.6207E-05 -0.4191E-13  0.0000E+00  0.0000E+00
* -0.6207E-05  0.8585E-04 -0.3406E-04 -0.2220E-12  0.0000E+00  0.0000E+00
* -0.6207E-05 -0.3406E-04  0.8585E-04  0.5913E-12  0.0000E+00  0.0000E+00
* -0.4191E-13 -0.2220E-12  0.5913E-12  0.2398E-03  0.0000E+00  0.0000E+00
*  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.2219E-03 -0.3729E-10
*  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -0.3729E-10  0.2219E-03
*****************************************************************************

*****************************************************************************
*
*  E1   =  0.433152D+05     E2   =  0.116479D+05     E3   =  0.116479D+05   *
*
*  NU23 =  0.396722D+00     NU12 =  0.268842D+00     NU13 =  0.268842D+00   *
*
*  G23  =  0.416972D+04     G12  =  0.450693D+04     G13  =  0.450692D+04   *
*
*****************************************************************************
 GENERIC NAME :
T8
IFIB ? ( = 1 ISOTROPIC CIRCULAR FIBER)
       ( = 2 ORTHOTROPIC CIRCULAR FIBER)
       ( = 3 ISOTROPIC KIDNEY FIBER)
       ( = 4 ORTHOTROPIC KIDNEY FIBER)
       ( = 5 ISOTROPIC STAGGERED FIBER)
       ( = 6 ORTHOTROPIC STAGGERED FIBER)
       ( = 7 HEXAGONAL CELL ISOTROPIC KIDNEY FIBER)
       ( = 8 HEXAGONAL CELL ORTHOTROPIC KIDNEY FIBER)
8
RATIO = ? ( TXMIN = 0.3961 )
.5
E1 , E2 , E3 = ? (ORTHOTROPIC FIBERS // A X1)
380000. 14500. 14500.
G12 , G13 , G23 = ? (ORTHOTROPIC FIBERS // A X1)
38000. 38000. 20000.
NU12 , NU13 , NU23 = ? (ORTHOTROPIC FIBERS // A X1)
.22 .22 .25
E , NU = ? (YOUNG MODULUS POISSON COEFF. ISOTROPIC RESIN)
3520. .38

THE FIBERS  ARE  PARALLEL AT  X1
*********************************

NOTATIONS      E1,E2,E3: YOUNG  MODULI  FIBER (COMPOSITE) DIRECTIONS X1,X2,X3
*********      GIJ     : FIBER ( COMPOSITE )  SHEAR  MODULI
               NU(IJ)  : FIBER ( COMPOSITE )  POISSON COEFFICIENT
               ER      : RESIN  YOUNG  MODULUS
               NUR     : RESIN  POISSON  COEFFICIENT
               NEL     : NUMBER OF ELEMENTS
               NOE     : NUMBER OF NODES
               TXR     : RESIN IMPREGNATED RATIO IN VOLUME

*****************************************************************************

*HEXAGONAL  CELL  FIBER  ORTHOTROPIC KIDNEY *ISOTROPIC RESIN*   MESH        *

*.........................................*.............*...................*
```

E1 = 380000.	G12 = 38000.	NU12 = 0.220	ER = 3520.	NEL = 498
E2 = 14500.	G13 = 38000.	NU13 = 0.220		NOE = 274
E3 = 14500.	G23 = 20000.	NU23 = 0.250	NUR = 0.380	TXR = .5089

HOMOGENIZED ELASTIC TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.1909E+06	0.4127E+04	0.4128E+04	-0.2039E-05	0.0000E+00	0.0000E+00
0.4127E+04	0.9448E+04	0.4488E+04	0.7904E-05	0.0000E+00	0.0000E+00
0.4128E+04	0.4488E+04	0.9477E+04	0.2161E-04	0.0000E+00	0.0000E+00
-0.2039E-05	0.7904E-05	0.2161E-04	0.3341E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3980E+04	0.2958E-02
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2958E-02	0.3980E+04

HOMOGENIZED COMPLIANCE TENSOR

1 1	2 2	3 3	2 3	1 3	1 2
0.5307E-05	-0.1574E-05	-0.1566E-05	0.1710E-13	0.0000E+00	0.0000E+00
-0.1574E-05	0.1370E-03	-0.6420E-04	0.9021E-13	0.0000E+00	0.0000E+00
-0.1566E-05	-0.6420E-04	0.1366E-03	-0.7328E-12	0.0000E+00	0.0000E+00
0.1710E-13	0.9021E-13	-0.7328E-12	0.2993E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2513E-03	-0.1867E-09
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.1867E-09	0.2513E-03

E1 = 0.188440D+06	E2 = 0.729813D+04	E3 = 0.732080D+04
NU23 = 0.466510D+00	NU12 = 0.296674D+00	NU13 = 0.295099D+00
G23 = 0.334081D+04	G12 = 0.397974D+04	G13 = 0.397974D+04

ROTATION 45 DEGREES AROUND X1

HOMOGENIZED COMPLIANCE TENSOR (BISECTING DIRECTIONS)

1 1	2 2	3 3	2 3	1 3	1 2
0.5307E-05	-0.1570E-05	-0.1570E-05	0.8355E-08	0.0000E+00	0.0000E+00
-0.1570E-05	0.1111E-03	-0.3853E-04	-0.2122E-06	0.0000E+00	0.0000E+00
-0.1570E-05	-0.3853E-04	0.1111E-03	-0.2122E-06	0.0000E+00	0.0000E+00
0.8355E-08	-0.2122E-06	-0.2122E-06	0.4020E-03	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2513E-03	-0.1117E-10
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.1117E-10	0.2513E-03

E1 = 0.188440D+06	E2 = 0.899775D+04	E3 = 0.899775D+04
NU23 = 0.346643D+00	NU12 = 0.295886D+00	NU13 = 0.295886D+00
G23 = 0.248750D+04	G12 = 0.397974D+04	G13 = 0.397973D+04

Listing 2: Evaluation of Microstress Fields

```
=========
C O M P O     15-JUL-1987 at 12:21:55
=========

HOMOGENIZATION   LAMINATED   COMPOSITE
==========================================


***************************************************************************
*            STAGGERED  FIBERS  PARALLEL  TO  THE  AXIS  X3              *
*                                                                         *
*                          N        N                                     *
*                    ( X )    ( Y )                 A =  0.28209479D-03   *
*  FIBER SECTION :  (---) + (---) = 1  ;  WITH :  B =  0.28209479D-03   *
*                    ( A )    ( B )                 N =  0.20000000D+01   *
*                                                                         *
*   SPACING  OF  FIBERS  :  IN X = 0.1000D-02     IN Y = 0.1000D-02      *
*                                                                         *
*   NUMBER OF ELEMENTS =  104   NUMBER OF NODES =   69   RESIN RATIO = .5130  *
*                                                                         *
*.........................................................................*
*                    ISOTROPIC  RESIN  CHARACTERISTICS                    *
*                                                                         *
*  YOUNG'S MODULUS =    3520.0        POISSON'S COEFFICIENT =   0.38000   *
*                                                                         *
*.........................................................................*
*                   ORTHOTROPIC  FIBER  CHARACTERISTICS                   *
*                                                                         *
*   E1   =  0.380000D+06     E2   =  0.145000D+05     E3   =  0.145000D+05  *
*   G23  =  0.200000D+05     G13  =  0.380000D+05     G12  =  0.380000D+05  *
*   NU23 =  0.250000D+00     NU13 =  0.220000D+00     NU12 =  0.220000D+00  *
*                                                                         *
***************************************************************************

***************************************************************************
*                     HOMOGENIZED  ELASTIC  TENSOR                        *
*.........................................................................*
*      1 1          2 2          3 3          2 3          1 3          1 2      *
*   0.1336E+05  0.5647E+04  0.4021E+04  0.0000E+00  0.0000E+00  0.3978E-12  *
*               0.9492E+04  0.3999E+04  0.0000E+00  0.0000E+00 -0.5453E-13  *
*                           0.1094E+05  0.0000E+00  0.0000E+00  0.5360E-14  *
*                                       0.3472E+04  0.3325E-03  0.0000E+00  *
*                                                   0.3767E+04  0.0000E+00  *
*                                                               0.5600E+04  *
***************************************************************************

***************************************************************************
*                    HOMOGENIZED  COMPLIANCE  TENSOR                      *
*.........................................................................*
*      1 1          2 2          3 3          2 3          1 3          1 2      *
*   0.1030E-03 -0.5359E-04 -0.1828E-04  0.0000E+00  0.0000E+00 -0.7823E-20  *
*               0.1524E-03 -0.3604E-04  0.0000E+00  0.0000E+00  0.5326E-20  *
*                           0.1113E-03  0.0000E+00  0.0000E+00  0.8409E-21  *
*                                       0.2880E-03 -0.2542E-10  0.0000E+00  *
*                                                   0.2655E-03  0.0000E+00  *
*                                                               0.1786E-03  *
```

EQUIVALENT MODULI

E1 = 0.970682D+04	E2 = 0.656066D+04	E3 = 0.898111D+04
G23 = 0.347231D+04	G13 = 0.376700D+04	G12 = 0.559991D+04
NU23 = 0.236448D+00	NU13 = 0.177422D+00	NU12 = 0.520184D+00

M E S H

NUMBER OF ELEMENTS : 104 NUMBER OF NODES : 28

SD = 1 --> FIBER
SD = 2 --> RESIN

ELE	SD	NODES					NODES COORDINATES			
1	1	2	1	3	0	X	-5.000E-04	-5.000E-04	-3.590E-04	0.000E+00
						Y	-3.590E-04	-5.000E-04	-5.000E-04	0.000E+00
2	1	2	3	10	0	X	-5.000E-04	-3.590E-04	-3.005E-04	0.000E+00
						Y	-3.590E-04	-5.000E-04	-3.005E-04	0.000E+00
3	1	2	9	8	0	X	-5.000E-04	-3.839E-04	-5.000E-04	0.000E+00
						Y	-3.590E-04	-2.429E-04	-2.179E-04	0.000E+00
4	1	2	10	9	0	X	-5.000E-04	-3.005E-04	-3.839E-04	0.000E+00
						Y	-3.590E-04	-3.005E-04	-2.429E-04	0.000E+00
5	1	10	3	11	0	X	-3.005E-04	-3.590E-04	-2.429E-04	0.000E+00
						Y	-3.005E-04	-5.000E-04	-3.839E-04	0.000E+00
6	1	11	3	4	0	X	-2.429E-04	-3.590E-04	-2.179E-04	0.000E+00
						Y	-3.839E-04	-5.000E-04	-5.000E-04	0.000E+00
7	2	11	4	12	0	X	-2.429E-04	-2.179E-04	-1.090E-04	0.000E+00
						Y	-3.839E-04	-5.000E-04	-5.000E-04	0.000E+00
8	1	13	14	5	0	X	5.000E-04	3.590E-04	5.000E-04	0.000E+00
						Y	-3.590E-04	-5.000E-04	-5.000E-04	0.000E+00
9	2	16	12	6	0	X	0.000E+00	-1.090E-04	0.000E+00	0.000E+00
						Y	-3.910E-04	-5.000E-04	-5.000E-04	0.000E+00
10	2	16	6	15	0	X	0.000E+00	0.000E+00	1.090E-04	0.000E+00
						Y	-3.910E-04	-5.000E-04	-5.000E-04	0.000E+00
11	1	17	7	14	0	X	2.429E-04	2.179E-04	3.590E-04	0.000E+00
						Y	-3.839E-04	-5.000E-04	-5.000E-04	0.000E+00
12	2	17	15	7	0	X	2.429E-04	1.090E-04	2.179E-04	0.000E+00
						Y	-3.839E-04	-5.000E-04	-5.000E-04	0.000E+00
13	2	9	18	8	0	X	-3.839E-04	-5.000E-04	-5.000E-04	0.000E+00
						Y	-2.429E-04	-1.090E-04	-2.179E-04	0.000E+00
14	2	9	19	18	0	X	-3.839E-04	-2.571E-04	-5.000E-04	0.000E+00
						Y	-2.429E-04	-1.161E-04	-1.090E-04	0.000E+00
15	2	10	19	9	0	X	-3.005E-04	-2.571E-04	-3.839E-04	0.000E+00
						Y	-3.005E-04	-1.161E-04	-2.429E-04	0.000E+00
16	2	10	21	20	0	X	-3.005E-04	-1.161E-04	-1.995E-04	0.000E+00
						Y	-3.005E-04	-2.571E-04	-1.995E-04	0.000E+00
17	2	11	21	10	0	X	-2.429E-04	-1.161E-04	-3.005E-04	0.000E+00
						Y	-3.839E-04	-2.571E-04	-3.005E-04	0.000E+00

18	2	10	20	19	0	X	-3.005E-04	-1.995E-04	-2.571E-04	0.000E+00
						Y	-3.005E-04	-1.995E-04	-1.161E-04	0.000E+00
19	2	11	12	21	0	X	-2.429E-04	-1.090E-04	-1.161E-04	0.000E+00
						Y	-3.839E-04	-5.000E-04	-2.571E-04	0.000E+00
20	2	21	12	16	0	X	-1.161E-04	-1.090E-04	0.000E+00	0.000E+00
						Y	-2.571E-04	-5.000E-04	-3.910E-04	0.000E+00
21	1	13	23	24	0	X	5.000E-04	3.839E-04	3.005E-04	0.000E+00
						Y	-3.590E-04	-2.429E-04	-3.005E-04	0.000E+00
22	1	13	24	14	0	X	5.000E-04	3.005E-04	3.590E-04	0.000E+00
						Y	-3.590E-04	-3.005E-04	-5.000E-04	0.000E+00
23	1	13	22	23	0	X	5.000E-04	5.000E-04	3.839E-04	0.000E+00
						Y	-3.590E-04	-2.179E-04	-2.429E-04	0.000E+00
24	1	24	17	14	0	X	3.005E-04	2.429E-04	3.590E-04	0.000E+00
						Y	-3.005E-04	-3.839E-04	-5.000E-04	0.000E+00
25	2	17	25	15	0	X	2.429E-04	1.161E-04	1.090E-04	0.000E+00
						Y	-3.839E-04	-2.571E-04	-5.000E-04	0.000E+00
26	2	25	16	15	0	X	1.161E-04	0.000E+00	1.090E-04	0.000E+00
						Y	-2.571E-04	-3.910E-04	-5.000E-04	0.000E+00
27	2	21	16	26	0	X	-1.161E-04	0.000E+00	0.000E+00	0.000E+00
						Y	-2.571E-04	-3.910E-04	-2.821E-04	0.000E+00
28	2	25	26	16	0	X	1.161E-04	0.000E+00	0.000E+00	0.000E+00
						Y	-2.571E-04	-2.821E-04	-3.910E-04	0.000E+00
29	2	17	24	25	0	X	2.429E-04	3.005E-04	1.161E-04	0.000E+00
						Y	-3.839E-04	-3.005E-04	-2.571E-04	0.000E+00
30	2	18	19	28	0	X	-5.000E-04	-2.571E-04	-3.910E-04	0.000E+00
						Y	-1.090E-04	-1.161E-04	0.000E+00	0.000E+00
31	2	18	28	27	0	X	-5.000E-04	-3.910E-04	-5.000E-04	0.000E+00
						Y	-1.090E-04	0.000E+00	0.000E+00	0.000E+00
32	1	19	30	29	0	X	-2.571E-04	-1.410E-04	-2.821E-04	0.000E+00
						Y	-1.161E-04	0.000E+00	0.000E+00	0.000E+00
33	2	28	19	29	0	X	-3.910E-04	-2.571E-04	-2.821E-04	0.000E+00
						Y	0.000E+00	-1.161E-04	0.000E+00	0.000E+00
34	1	20	30	19	0	X	-1.995E-04	-1.410E-04	-2.571E-04	0.000E+00
						Y	-1.995E-04	0.000E+00	-1.161E-04	0.000E+00
35	1	21	31	20	0	X	-1.161E-04	0.000E+00	-1.995E-04	0.000E+00
						Y	-2.571E-04	-1.410E-04	-1.995E-04	0.000E+00
36	1	20	31	30	0	X	-1.995E-04	0.000E+00	-1.410E-04	0.000E+00
						Y	-1.995E-04	-1.410E-04	0.000E+00	0.000E+00
37	1	21	26	31	0	X	-1.161E-04	0.000E+00	0.000E+00	0.000E+00
						Y	-2.571E-04	-2.821E-04	-1.410E-04	0.000E+00
38	2	23	22	32	0	X	3.839E-04	5.000E-04	5.000E-04	0.000E+00
						Y	-2.429E-04	-2.179E-04	-1.090E-04	0.000E+00
39	2	24	23	33	0	X	3.005E-04	3.839E-04	2.571E-04	0.000E+00
						Y	-3.005E-04	-2.429E-04	-1.161E-04	0.000E+00
40	2	23	32	33	0	X	3.839E-04	5.000E-04	2.571E-04	0.000E+00
						Y	-2.429E-04	-1.090E-04	-1.161E-04	0.000E+00
41	2	24	33	34	0	X	3.005E-04	2.571E-04	1.995E-04	0.000E+00
						Y	-3.005E-04	-1.161E-04	-1.995E-04	0.000E+00
42	2	24	34	25	0	X	3.005E-04	1.995E-04	1.161E-04	0.000E+00
						Y	-3.005E-04	-1.995E-04	-2.571E-04	0.000E+00
43	1	25	34	31	0	X	1.161E-04	1.995E-04	0.000E+00	0.000E+00
						Y	-2.571E-04	-1.995E-04	-1.410E-04	0.000E+00
44	1	25	31	26	0	X	1.161E-04	0.000E+00	0.000E+00	0.000E+00
						Y	-2.571E-04	-1.410E-04	-2.821E-04	0.000E+00
45	2	36	27	28	0	X	-5.000E-04	-5.000E-04	-3.910E-04	0.000E+00
						Y	1.090E-04	0.000E+00	0.000E+00	0.000E+00
46	2	36	28	37	0	X	-5.000E-04	-3.910E-04	-2.571E-04	0.000E+00
						Y	1.090E-04	0.000E+00	1.161E-04	0.000E+00
47	2	28	29	37	0	X	-3.910E-04	-2.821E-04	-2.571E-04	0.000E+00
						Y	0.000E+00	0.000E+00	1.161E-04	0.000E+00

48	!	1	!	37	29	30	0	!	X	:	-2.571E-04	-2.821E-04	-1.410E-04	0.000E+00
								!	Y	:	1.161E-04	0.000E+00	0.000E+00	0.000E+00
49	!	1	!	30	35	39	0	!	X	:	-1.410E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	0.000E+00	0.000E+00	1.410E-04	0.000E+00
50	!	1	!	38	30	39	0	!	X	:	-1.995E-04	-1.410E-04	0.000E+00	0.000E+00
								!	Y	:	1.995E-04	0.000E+00	1.410E-04	0.000E+00
51	!	1	!	30	31	35	0	!	X	:	-1.410E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	0.000E+00	-1.410E-04	0.000E+00	0.000E+00
52	!	1	!	38	37	30	0	!	X	:	-1.995E-04	-2.571E-04	-1.410E-04	0.000E+00
								!	Y	:	1.995E-04	1.161E-04	0.000E+00	0.000E+00
53	!	1	!	34	40	31	0	!	X	:	1.995E-04	1.410E-04	0.000E+00	0.000E+00
								!	Y	:	-1.995E-04	0.000E+00	-1.410E-04	0.000E+00
54	!	1	!	40	35	31	0	!	X	:	1.410E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	0.000E+00	0.000E+00	-1.410E-04	0.000E+00
55	!	2	!	32	41	42	0	!	X	:	5.000E-04	5.000E-04	3.910E-04	0.000E+00
								!	Y	:	-1.090E-04	0.000E+00	0.000E+00	0.000E+00
56	!	2	!	32	42	33	0	!	X	:	5.000E-04	3.910E-04	2.571E-04	0.000E+00
								!	Y	:	-1.090E-04	0.000E+00	-1.161E-04	0.000E+00
57	!	1	!	33	43	40	0	!	X	:	2.571E-04	2.821E-04	1.410E-04	0.000E+00
								!	Y	:	-1.161E-04	0.000E+00	0.000E+00	0.000E+00
58	!	2	!	42	43	33	0	!	X	:	3.910E-04	2.821E-04	2.571E-04	0.000E+00
								!	Y	:	0.000E+00	0.000E+00	-1.161E-04	0.000E+00
59	!	1	!	34	33	40	0	!	X	:	1.995E-04	2.571E-04	1.410E-04	0.000E+00
								!	Y	:	-1.995E-04	-1.161E-04	0.000E+00	0.000E+00
60	!	1	!	40	39	35	0	!	X	:	1.410E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	0.000E+00	1.410E-04	0.000E+00	0.000E+00
61	!	2	!	45	44	36	0	!	X	:	-3.839E-04	-5.000E-04	-5.000E-04	0.000E+00
								!	Y	:	2.429E-04	2.179E-04	1.090E-04	0.000E+00
62	!	2	!	45	36	37	0	!	X	:	-3.839E-04	-5.000E-04	-2.571E-04	0.000E+00
								!	Y	:	2.429E-04	1.090E-04	1.161E-04	0.000E+00
63	!	2	!	46	37	38	0	!	X	:	-3.005E-04	-2.571E-04	-1.995E-04	0.000E+00
								!	Y	:	3.005E-04	1.161E-04	1.995E-04	0.000E+00
64	!	2	!	46	45	37	0	!	X	:	-3.005E-04	-3.839E-04	-2.571E-04	0.000E+00
								!	Y	:	3.005E-04	2.429E-04	1.161E-04	0.000E+00
65	!	2	!	46	38	47	0	!	X	:	-3.005E-04	-1.995E-04	-1.161E-04	0.000E+00
								!	Y	:	3.005E-04	1.995E-04	2.571E-04	0.000E+00
66	!	1	!	47	38	39	0	!	X	:	-1.161E-04	-1.995E-04	0.000E+00	0.000E+00
								!	Y	:	2.571E-04	1.995E-04	1.410E-04	0.000E+00
67	!	1	!	49	39	40	0	!	X	:	1.995E-04	0.000E+00	1.410E-04	0.000E+00
								!	Y	:	1.995E-04	1.410E-04	0.000E+00	0.000E+00
68	!	1	!	50	48	39	0	!	X	:	1.161E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	2.571E-04	2.821E-04	1.410E-04	0.000E+00
69	!	1	!	50	39	49	0	!	X	:	1.161E-04	0.000E+00	1.995E-04	0.000E+00
								!	Y	:	2.571E-04	1.410E-04	1.995E-04	0.000E+00
70	!	1	!	47	39	48	0	!	X	:	-1.161E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	2.571E-04	1.410E-04	2.821E-04	0.000E+00
71	!	1	!	49	40	51	0	!	X	:	1.995E-04	1.410E-04	2.571E-04	0.000E+00
								!	Y	:	1.995E-04	0.000E+00	1.161E-04	0.000E+00
72	!	1	!	51	40	43	0	!	X	:	2.571E-04	1.410E-04	2.821E-04	0.000E+00
								!	Y	:	1.161E-04	0.000E+00	0.000E+00	0.000E+00
73	!	2	!	52	42	41	0	!	X	:	5.000E-04	3.910E-04	5.000E-04	0.000E+00
								!	Y	:	1.090E-04	0.000E+00	0.000E+00	0.000E+00
74	!	2	!	52	51	42	0	!	X	:	5.000E-04	2.571E-04	3.910E-04	0.000E+00
								!	Y	:	1.090E-04	1.161E-04	0.000E+00	0.000E+00
75	!	2	!	42	51	43	0	!	X	:	3.910E-04	2.571E-04	2.821E-04	0.000E+00
								!	Y	:	0.000E+00	1.161E-04	0.000E+00	0.000E+00
76	!	1	!	53	44	45	0	!	X	:	-5.000E-04	-5.000E-04	-3.839E-04	0.000E+00
								!	Y	:	3.590E-04	2.179E-04	2.429E-04	0.000E+00
77	!	1	!	53	45	46	0	!	X	:	-5.000E-04	-3.839E-04	-3.005E-04	0.000E+00
								!	Y	:	3.590E-04	2.429E-04	3.005E-04	0.000E+00

48	!	1	!	37	29	30	0	!	X	:	-2.571E-04	-2.821E-04	-1.410E-04	0.000E+00
								!	Y	:	1.161E-04	0.000E+00	0.000E+00	0.000E+00
49	!	1	!	30	35	39	0	!	X	:	-1.410E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	0.000E+00	0.000E+00	1.410E-04	0.000E+00
50	!	1	!	38	30	39	0	!	X	:	-1.995E-04	-1.410E-04	0.000E+00	0.000E+00
								!	Y	:	1.995E-04	0.000E+00	1.410E-04	0.000E+00
51	!	1	!	30	31	35	0	!	X	:	-1.410E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	0.000E+00	-1.410E-04	0.000E+00	0.000E+00
52	!	1	!	38	37	30	0	!	X	:	-1.995E-04	-2.571E-04	-1.410E-04	0.000E+00
								!	Y	:	1.995E-04	1.161E-04	0.000E+00	0.000E+00
53	!	1	!	34	40	31	0	!	X	:	1.995E-04	1.410E-04	0.000E+00	0.000E+00
								!	Y	:	-1.995E-04	0.000E+00	-1.410E-04	0.000E+00
54	!	1	!	40	35	31	0	!	X	:	1.410E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	0.000E+00	0.000E+00	-1.410E-04	0.000E+00
55	!	2	!	32	41	42	0	!	X	:	5.000E-04	5.000E-04	3.910E-04	0.000E+00
								!	Y	:	-1.090E-04	0.000E+00	0.000E+00	0.000E+00
56	!	2	!	32	42	33	0	!	X	:	5.000E-04	3.910E-04	2.571E-04	0.000E+00
								!	Y	:	-1.090E-04	0.000E+00	-1.161E-04	0.000E+00
57	!	1	!	33	43	40	0	!	X	:	2.571E-04	2.821E-04	1.410E-04	0.000E+00
								!	Y	:	-1.161E-04	0.000E+00	0.000E+00	0.000E+00
58	!	2	!	42	43	33	0	!	X	:	3.910E-04	2.821E-04	2.571E-04	0.000E+00
								!	Y	:	0.000E+00	0.000E+00	-1.161E-04	0.000E+00
59	!	1	!	34	33	40	0	!	X	:	1.995E-04	2.571E-04	1.410E-04	0.000E+00
								!	Y	:	-1.995E-04	-1.161E-04	0.000E+00	0.000E+00
60	!	1	!	40	39	35	0	!	X	:	1.410E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	0.000E+00	1.410E-04	0.000E+00	0.000E+00
61	!	2	!	45	44	36	0	!	X	:	-3.839E-04	-5.000E-04	-5.000E-04	0.000E+00
								!	Y	:	2.429E-04	2.179E-04	1.090E-04	0.000E+00
62	!	2	!	45	36	37	0	!	X	:	-3.839E-04	-5.000E-04	-2.571E-04	0.000E+00
								!	Y	:	2.429E-04	1.090E-04	1.161E-04	0.000E+00
63	!	2	!	46	37	38	0	!	X	:	-3.005E-04	-2.571E-04	-1.995E-04	0.000E+00
								!	Y	:	3.005E-04	1.161E-04	1.995E-04	0.000E+00
64	!	2	!	46	45	37	0	!	X	:	-3.005E-04	-3.839E-04	-2.571E-04	0.000E+00
								!	Y	:	3.005E-04	2.429E-04	1.161E-04	0.000E+00
65	!	2	!	46	38	47	0	!	X	:	-3.005E-04	-1.995E-04	-1.161E-04	0.000E+00
								!	Y	:	3.005E-04	1.995E-04	2.571E-04	0.000E+00
66	!	1	!	47	38	39	0	!	X	:	-1.161E-04	-1.995E-04	0.000E+00	0.000E+00
								!	Y	:	2.571E-04	1.995E-04	1.410E-04	0.000E+00
67	!	1	!	49	39	40	0	!	X	:	1.995E-04	0.000E+00	1.410E-04	0.000E+00
								!	Y	:	1.995E-04	1.410E-04	0.000E+00	0.000E+00
68	!	1	!	50	48	39	0	!	X	:	1.161E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	2.571E-04	2.821E-04	1.410E-04	0.000E+00
69	!	1	!	50	39	49	0	!	X	:	1.161E-04	0.000E+00	1.995E-04	0.000E+00
								!	Y	:	2.571E-04	1.410E-04	1.995E-04	0.000E+00
70	!	1	!	47	39	48	0	!	X	:	-1.161E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	2.571E-04	1.410E-04	2.821E-04	0.000E+00
71	!	1	!	49	40	51	0	!	X	:	1.995E-04	1.410E-04	2.571E-04	0.000E+00
								!	Y	:	1.995E-04	0.000E+00	1.161E-04	0.000E+00
72	!	1	!	51	40	43	0	!	X	:	2.571E-04	1.410E-04	2.821E-04	0.000E+00
								!	Y	:	1.161E-04	0.000E+00	0.000E+00	0.000E+00
73	!	2	!	52	42	41	0	!	X	:	5.000E-04	3.910E-04	5.000E-04	0.000E+00
								!	Y	:	1.090E-04	0.000E+00	0.000E+00	0.000E+00
74	!	2	!	52	51	42	0	!	X	:	5.000E-04	2.571E-04	3.910E-04	0.000E+00
								!	Y	:	1.090E-04	1.161E-04	0.000E+00	0.000E+00
75	!	2	!	42	51	43	0	!	X	:	3.910E-04	2.571E-04	2.821E-04	0.000E+00
								!	Y	:	0.000E+00	1.161E-04	0.000E+00	0.000E+00
76	!	1	!	53	44	45	0	!	X	:	-5.000E-04	-5.000E-04	-3.839E-04	0.000E+00
								!	Y	:	3.590E-04	2.179E-04	2.429E-04	0.000E+00
77	!	1	!	53	45	46	0	!	X	:	-5.000E-04	-3.839E-04	-3.005E-04	0.000E+00
								!	Y	:	3.590E-04	2.429E-04	3.005E-04	0.000E+00

78	!	1	!	46	54	55	0	!	X	:	-3.005E-04	-2.429E-04	-3.590E-04	0.000E+00
								!	Y	:	3.005E-04	3.839E-04	5.000E-04	0.000E+00
79	!	2	!	54	46	47	0	!	X	:	-2.429E-04	-3.005E-04	-1.161E-04	0.000E+00
								!	Y	:	3.839E-04	3.005E-04	2.571E-04	0.000E+00
80	!	1	!	53	46	55	0	!	X	:	-5.000E-04	-3.005E-04	-3.590E-04	0.000E+00
								!	Y	:	3.590E-04	3.005E-04	5.000E-04	0.000E+00
81	!	2	!	54	47	56	0	!	X	:	-2.429E-04	-1.161E-04	-1.090E-04	0.000E+00
								!	Y	:	3.839E-04	2.571E-04	5.000E-04	0.000E+00
82	!	2	!	47	57	56	0	!	X	:	-1.161E-04	0.000E+00	-1.090E-04	0.000E+00
								!	Y	:	2.571E-04	3.910E-04	5.000E-04	0.000E+00
83	!	2	!	47	48	57	0	!	X	:	-1.161E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	2.571E-04	2.821E-04	3.910E-04	0.000E+00
84	!	2	!	50	57	48	0	!	X	:	1.161E-04	0.000E+00	0.000E+00	0.000E+00
								!	Y	:	2.571E-04	3.910E-04	2.821E-04	0.000E+00
85	!	2	!	58	49	51	0	!	X	:	3.005E-04	1.995E-04	2.571E-04	0.000E+00
								!	Y	:	3.005E-04	1.995E-04	1.161E-04	0.000E+00
86	!	2	!	58	50	49	0	!	X	:	3.005E-04	1.161E-04	1.995E-04	0.000E+00
								!	Y	:	3.005E-04	2.571E-04	1.995E-04	0.000E+00
87	!	2	!	60	59	50	0	!	X	:	2.429E-04	1.090E-04	1.161E-04	0.000E+00
								!	Y	:	3.839E-04	5.000E-04	2.571E-04	0.000E+00
88	!	2	!	50	59	57	0	!	X	:	1.161E-04	1.090E-04	0.000E+00	0.000E+00
								!	Y	:	2.571E-04	5.000E-04	3.910E-04	0.000E+00
89	!	2	!	60	50	58	0	!	X	:	2.429E-04	1.161E-04	3.005E-04	0.000E+00
								!	Y	:	3.839E-04	2.571E-04	3.005E-04	0.000E+00
90	!	2	!	58	51	61	0	!	X	:	3.005E-04	2.571E-04	3.839E-04	0.000E+00
								!	Y	:	3.005E-04	1.161E-04	2.429E-04	0.000E+00
91	!	2	!	61	51	52	0	!	X	:	3.839E-04	2.571E-04	5.000E-04	0.000E+00
								!	Y	:	2.429E-04	1.161E-04	1.090E-04	0.000E+00
92	!	2	!	61	52	62	0	!	X	:	3.839E-04	5.000E-04	5.000E-04	0.000E+00
								!	Y	:	2.429E-04	1.090E-04	2.179E-04	0.000E+00
93	!	1	!	53	55	63	0	!	X	:	-5.000E-04	-3.590E-04	-5.000E-04	0.000E+00
								!	Y	:	3.590E-04	5.000E-04	5.000E-04	0.000E+00
94	!	2	!	54	56	64	0	!	X	:	-2.429E-04	-1.090E-04	-2.179E-04	0.000E+00
								!	Y	:	3.839E-04	5.000E-04	5.000E-04	0.000E+00
95	!	1	!	54	64	55	0	!	X	:	-2.429E-04	-2.179E-04	-3.590E-04	0.000E+00
								!	Y	:	3.839E-04	5.000E-04	5.000E-04	0.000E+00
96	!	2	!	57	65	56	0	!	X	:	0.000E+00	0.000E+00	-1.090E-04	0.000E+00
								!	Y	:	3.910E-04	5.000E-04	5.000E-04	0.000E+00
97	!	2	!	57	59	65	0	!	X	:	0.000E+00	1.090E-04	0.000E+00	0.000E+00
								!	Y	:	3.910E-04	5.000E-04	5.000E-04	0.000E+00
98	!	1	!	67	58	61	0	!	X	:	5.000E-04	3.005E-04	3.839E-04	0.000E+00
								!	Y	:	3.590E-04	3.005E-04	2.429E-04	0.000E+00
99	!	1	!	67	66	58	0	!	X	:	5.000E-04	3.590E-04	3.005E-04	0.000E+00
								!	Y	:	3.590E-04	5.000E-04	3.005E-04	0.000E+00
100	!	1	!	58	66	60	0	!	X	:	3.005E-04	3.590E-04	2.429E-04	0.000E+00
								!	Y	:	3.005E-04	5.000E-04	3.839E-04	0.000E+00
101	!	2	!	60	68	59	0	!	X	:	2.429E-04	2.179E-04	1.090E-04	0.000E+00
								!	Y	:	3.839E-04	5.000E-04	5.000E-04	0.000E+00
102	!	1	!	60	66	68	0	!	X	:	2.429E-04	3.590E-04	2.179E-04	0.000E+00
								!	Y	:	3.839E-04	5.000E-04	5.000E-04	0.000E+00
103	!	1	!	67	61	62	0	!	X	:	5.000E-04	3.839E-04	5.000E-04	0.000E+00
								!	Y	:	3.590E-04	2.429E-04	2.179E-04	0.000E+00
104	!	1	!	67	69	66	0	!	X	:	5.000E-04	5.000E-04	3.590E-04	0.000E+00
								!	Y	:	3.590E-04	5.000E-04	5.000E-04	0.000E+00

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MACROSCOPIC STRESS FIELD

S(1,1) =	0.1000D+03	S(1,2) =	0.0000D+00	S(1,3) =	0.0000D+00
		S(2,2) =	0.0000D+00	S(2,3) =	0.0000D+00
				S(3,3) =	0.0000D+00

MACROSCOPIC STRAIN TENSOR

E(1,1) =	0.1030D-01	E(1,2) =	-0.5359D-02	E(1,3) =	-0.2436D-02
		E(2,2) =	0.0000D+00	E(2,3) =	0.0000D+00
				E(3,3) =	0.0000D+00

MICROSCOPIC STRESS FIELD

ELE	S11	S22	S33	S23	S13	S12
1	78.9	-5.11	-35.9	0.000E+00	0.000E+00	7.378E-15
2	134.	-7.62	-36.1	0.000E+00	0.000E+00	-2.12
3	174.	-7.87	-35.8	0.000E+00	0.000E+00	18.3
4	144.	6.43	-32.5	0.000E+00	0.000E+00	-14.3
5	98.4	-9.18	-36.8	0.000E+00	0.000E+00	8.67
6	90.4	-8.42	-36.7	0.000E+00	0.000E+00	7.40
7	78.5	44.3	38.1	0.000E+00	0.000E+00	3.86
8	78.9	-5.11	-35.9	0.000E+00	0.000E+00	-8.520E-15
9	114.	-30.4	23.3	0.000E+00	0.000E+00	1.344E-14
10	114.	-30.4	23.3	0.000E+00	0.000E+00	1.334E-14
11	90.4	-8.42	-36.7	0.000E+00	0.000E+00	-7.40
12	78.5	44.3	38.1	0.000E+00	0.000E+00	-3.86
13	-17.7	-26.0	-25.2	0.000E+00	0.000E+00	-0.134
14	85.3	1.46	24.4	0.000E+00	0.000E+00	10.3
15	49.3	-23.4	1.27	0.000E+00	0.000E+00	17.6
16	64.7	-24.1	6.85	0.000E+00	0.000E+00	22.1
17	107.	24.2	41.2	0.000E+00	0.000E+00	3.85
18	139.	37.8	58.6	0.000E+00	0.000E+00	5.73
19	101.	9.03	33.1	0.000E+00	0.000E+00	6.40
20	61.2	-15.3	8.85	0.000E+00	0.000E+00	4.56
21	144.	6.43	-32.5	0.000E+00	0.000E+00	14.3
22	134.	-7.62	-36.1	0.000E+00	0.000E+00	2.12
23	174.	-7.87	-35.8	0.000E+00	0.000E+00	-18.3
24	98.4	-9.18	-36.8	0.000E+00	0.000E+00	-8.67
25	101.	9.03	33.1	0.000E+00	0.000E+00	-6.40
26	61.2	-15.3	8.85	0.000E+00	0.000E+00	-4.56
27	-13.5	-20.0	-21.3	0.000E+00	0.000E+00	-2.524E-02
28	-13.5	-20.0	-21.3	0.000E+00	0.000E+00	2.524E-02
29	107.	24.2	41.2	0.000E+00	0.000E+00	-3.85
30	81.4	-3.15	21.2	0.000E+00	0.000E+00	-1.20
31	101.	-32.8	17.4	0.000E+00	0.000E+00	3.288E-15
32	106.	-12.4	-37.5	0.000E+00	0.000E+00	4.05
33	96.4	54.1	48.6	0.000E+00	0.000E+00	4.52
34	56.2	-8.08	-36.9	0.000E+00	0.000E+00	-2.85
35	123.	14.0	-30.8	0.000E+00	0.000E+00	-17.0
36	128.	-7.22	-36.0	0.000E+00	0.000E+00	-5.45
37	226.	-3.06	-34.2	0.000E+00	0.000E+00	16.9
38	-17.7	-26.0	-25.2	0.000E+00	0.000E+00	0.134
39	49.3	-23.4	1.27	0.000E+00	0.000E+00	-17.6
40	85.3	1.46	24.4	0.000E+00	0.000E+00	-10.3

41	139.	37.8	58.6	0.000E+00	0.000E+00	-5.73
42	64.7	-24.1	6.85	0.000E+00	0.000E+00	-22.1
43	123.	14.0	-30.8	0.000E+00	0.000E+00	17.0
44	226.	-3.06	-34.2	0.000E+00	0.000E+00	-16.9
45	101.	-32.8	17.4	0.000E+00	0.000E+00	-8.317E-15
46	81.4	-3.15	21.2	0.000E+00	0.000E+00	1.20
47	96.4	54.1	48.6	0.000E+00	0.000E+00	-4.52
48	106.	-12.4	-37.5	0.000E+00	0.000E+00	-4.05
49	59.0	-2.92	-35.6	0.000E+00	0.000E+00	-3.273E-14
50	128.	-7.22	-36.0	0.000E+00	0.000E+00	5.45
51	59.0	-2.92	-35.6	0.000E+00	0.000E+00	2.740E-14
52	56.2	-8.08	-36.9	0.000E+00	0.000E+00	2.85
53	128.	-7.22	-36.0	0.000E+00	0.000E+00	5.45
54	59.0	-2.92	-35.6	0.000E+00	0.000E+00	2.532E-14
55	101.	-32.8	17.4	0.000E+00	0.000E+00	2.994E-15
56	81.4	-3.15	21.2	0.000E+00	0.000E+00	1.20
57	106.	-12.4	-37.5	0.000E+00	0.000E+00	-4.05
58	96.4	54.1	48.6	0.000E+00	0.000E+00	-4.52
59	56.2	-8.08	-36.9	0.000E+00	0.000E+00	2.85
60	59.0	-2.92	-35.6	0.000E+00	0.000E+00	-3.481E-14
61	-17.7	-26.0	-25.2	0.000E+00	0.000E+00	0.134
62	85.3	1.46	24.4	0.000E+00	0.000E+00	-10.3
63	139.	37.8	58.6	0.000E+00	0.000E+00	-5.73
64	49.3	-23.4	1.27	0.000E+00	0.000E+00	-17.6
65	64.7	-24.1	6.85	0.000E+00	0.000E+00	-22.1
66	123.	14.0	-30.8	0.000E+00	0.000E+00	17.0
67	128.	-7.22	-36.0	0.000E+00	0.000E+00	-5.45
68	226.	-3.06	-34.2	0.000E+00	0.000E+00	16.9
69	123.	14.0	-30.8	0.000E+00	0.000E+00	-17.0
70	226.	-3.06	-34.2	0.000E+00	0.000E+00	-16.9
71	56.2	-8.08	-36.9	0.000E+00	0.000E+00	-2.85
72	106.	-12.4	-37.5	0.000E+00	0.000E+00	4.05
73	101.	-32.8	17.4	0.000E+00	0.000E+00	-8.611E-15
74	81.4	-3.15	21.2	0.000E+00	0.000E+00	-1.20
75	96.4	54.1	48.6	0.000E+00	0.000E+00	4.52
76	174.	-7.87	-35.8	0.000E+00	0.000E+00	-18.3
77	144.	6.43	-32.5	0.000E+00	0.000E+00	14.3
78	98.4	-9.18	-36.8	0.000E+00	0.000E+00	-8.67
79	107.	24.2	41.2	0.000E+00	0.000E+00	-3.85
80	134.	-7.62	-36.1	0.000E+00	0.000E+00	2.12
81	101.	9.03	33.1	0.000E+00	0.000E+00	-6.40
82	61.2	-15.3	8.85	0.000E+00	0.000E+00	-4.56
83	-13.5	-20.0	-21.3	0.000E+00	0.000E+00	2.524E-02
84	-13.5	-20.0	-21.3	0.000E+00	0.000E+00	-2.524E-02
85	139.	37.8	58.6	0.000E+00	0.000E+00	5.73
86	64.7	-24.1	6.85	0.000E+00	0.000E+00	22.1
87	101.	9.03	33.1	0.000E+00	0.000E+00	6.40
88	61.2	-15.3	8.85	0.000E+00	0.000E+00	4.56
89	107.	24.2	41.2	0.000E+00	0.000E+00	3.85
90	49.3	-23.4	1.27	0.000E+00	0.000E+00	17.6
91	85.3	1.46	24.4	0.000E+00	0.000E+00	10.3
92	-17.7	-26.0	-25.2	0.000E+00	0.000E+00	-0.134
93	78.9	-5.11	-35.9	0.000E+00	0.000E+00	7.048E-14
94	78.5	44.3	38.1	0.000E+00	0.000E+00	-3.86
95	90.4	-8.42	-36.7	0.000E+0C	0.000E+00	-7.40
96	114.	-30.4	23.3	0.000E+00	0.000E+00	-1.010E-14
97	114.	-30.4	23.3	0.000E+00	0.000E+00	-1.020E-14
98	144.	6.43	-32.5	0.000E+00	0.000E+00	-14.3
99	134.	-7.62	-36.1	0.000E+00	0.000E+00	-2.12
100	98.4	-9.18	-36.8	0.000E+00	0.000E+00	8.67

101	78.5	44.3	38.1	0.000E+00	0.000E+00	3.86
102	90.4	-8.42	-36.7	0.000E+00	0.000E+00	7.40
103	174.	-7.87	-35.8	0.000E+00	0.000E+00	18.3
104	78.9	-5.11	-35.9	0.000E+00	0.000E+00	5.458E-14

STRESS FORCE

NODE	X	Y	FX	FY	FZ
1	-3.8394E-04	-2.4289E-04	-30.33	-10.66	0.0000E+00
2	-3.0053E-04	-3.0053E-04	-65.44	14.42	0.0000E+00
3	-2.4289E-04	-3.8394E-04	-45.79	-2.453	0.0000E+00
4	2.4289E-04	-3.8394E-04	45.79	-2.453	0.0000E+00
5	-2.5711E-04	-1.1606E-04	27.14	-4.188	0.0000E+00
6	-1.9947E-04	-1.9947E-04	65.74	-14.76	0.0000E+00
7	-1.1606E-04	-2.5711E-04	48.35	14.00	0.0000E+00
8	3.8394E-04	-2.4289E-04	30.33	-10.66	0.0000E+00
9	3.0053E-04	-3.0053E-04	65.44	14.42	0.0000E+00
10	1.1606E-04	-2.5711E-04	-48.35	14.00	0.0000E+00
11	0.0000E+00	-2.8209E-04	9.1075E-06	-9.772	0.0000E+00
12	-2.8209E-04	0.0000E+00	49.65	-8.1103E-08	0.0000E+00
13	2.5711E-04	-1.1606E-04	-27.14	-4.188	0.0000E+00
14	1.9947E-04	-1.9947E-04	-65.74	-14.76	0.0000E+00
15	-2.5711E-04	1.1606E-04	27.14	4.188	0.0000E+00
16	-1.9947E-04	1.9947E-04	65.74	14.76	0.0000E+00
17	2.8209E-04	0.0000E+00	-49.65	8.1103E-08	0.0000E+00
18	-3.8394E-04	2.4289E-04	-30.33	10.66	0.0000E+00
19	-3.0053E-04	3.0053E-04	-65.44	-14.42	0.0000E+00
20	-1.1606E-04	2.5711E-04	48.35	-14.00	0.0000E+00
21	0.0000E+00	2.8209E-04	-9.1075E-06	9.772	0.0000E+00
22	1.9947E-04	1.9947E-04	-65.74	14.76	0.0000E+00
23	1.1606E-04	2.5711E-04	-48.35	-14.00	0.0000E+00
24	2.5711E-04	1.1606E-04	-27.14	4.188	0.0000E+00
25	-2.4289E-04	3.8394E-04	-45.79	2.453	0.0000E+00
26	3.0053E-04	3.0053E-04	65.44	-14.42	0.0000E+00
27	2.4289E-04	3.8394E-04	45.79	2.453	0.0000E+00
28	3.8394E-04	2.4289E-04	30.33	10.66	0.0000E+00

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MACROSCOPIC STRESS FIELD

S(1,1) = 0.0000D+00	S(1,2) = 0.1000D+03	S(1,3) = 0.0000D+00
	S(2,2) = 0.0000D+00	S(2,3) = 0.0000D+00
		S(3,3) = 0.0000D+00

MACROSCOPIC STRAIN TENSOR

E(1,1) = -0.5359D-02	E(1,2) = 0.1524D-01	E(1,3) = -0.3604D-02
	E(2,2) = 0.0000D+00	E(2,3) = 0.0000D+00
		E(3,3) = 0.0000D+00

MICROSCOPIC STRESS FIELD

ELE	S11	S22	S33	S23	S13	S12
1	16.2	114.	-23.6	0.000E+00	0.000E+00	-1.142E-14
2	-11.2	117.	-23.0	0.000E+00	0.000E+00	5.72
3	-39.7	106.	-26.2	0.000E+00	0.000E+00	5.81
4	-17.3	99.8	-27.5	0.000E+00	0.000E+00	18.8
5	19.2	118.	-22.6	0.000E+00	0.000E+00	3.73
6	-11.3	121.	-22.2	0.000E+00	0.000E+00	-0.590
7	-9.26	24.5	-6.90	0.000E+00	0.000E+00	-1.24
8	16.2	114.	-23.6	0.000E+00	0.000E+00	5.473E-15
9	-20.1	110.	21.6	0.000E+00	0.000E+00	-7.163E-15
10	-20.1	110.	21.6	0.000E+00	0.000E+00	-7.876E-15
11	-11.3	121.	-22.2	0.000E+00	0.000E+00	0.590
12	-9.26	24.5	-6.90	0.000E+00	0.000E+00	1.24
13	53.1	96.8	44.3	0.000E+00	0.000E+00	2.73
14	10.2	102.	29.8	0.000E+00	0.000E+00	1.52
15	24.2	106.	36.9	0.000E+00	0.000E+00	-0.737
16	23.9	119.	41.8	0.000E+00	0.000E+00	-0.852
17	-15.5	66.1	6.52	0.000E+00	0.000E+00	10.1
18	-27.9	66.5	1.98	0.000E+00	0.000E+00	11.7
19	3.42	92.9	23.9	0.000E+00	0.000E+00	4.59
20	8.38	95.3	26.7	0.000E+00	0.000E+00	-1.62
21	-17.3	99.8	-27.5	0.000E+00	0.000E+00	-18.8
22	-11.2	117.	-23.0	0.000E+00	0.000E+00	-5.72
23	-39.7	106.	-26.2	0.000E+00	0.000E+00	-5.81
24	19.2	118.	-22.6	0.000E+00	0.000E+00	-3.73
25	3.42	92.9	23.9	0.000E+00	0.000E+00	-4.59
26	8.38	95.3	26.7	0.000E+00	0.000E+00	1.62
27	58.0	105.	49.4	0.000E+00	0.000E+00	2.78
28	58.0	105.	49.4	0.000E+00	0.000E+00	-2.78
29	-15.5	66.1	6.52	0.000E+00	0.000E+00	-10.1
30	-2.12	81.3	17.4	0.000E+00	0.000E+00	2.71
31	-15.5	117.	26.0	0.000E+00	0.000E+00	-2.134E-15
32	-11.2	126.	-20.9	0.000E+00	0.000E+00	-0.994
33	-8.75	26.2	-6.06	0.000E+00	0.000E+00	-1.29
34	39.0	116.	-23.0	0.000E+00	0.000E+00	19.8
35	-12.0	89.6	-30.0	0.000E+00	0.000E+00	26.0
36	-9.76	117.	-23.2	0.000E+00	0.000E+00	8.30
37	-74.3	104.	-26.9	0.000E+00	0.000E+00	-4.56
38	53.1	96.8	44.3	0.000E+00	0.000E+00	-2.73
39	24.2	106.	36.9	0.000E+00	0.000E+00	0.737
40	10.2	102.	29.8	0.000E+00	0.000E+00	-1.52
41	-27.9	66.5	1.98	0.000E+00	0.000E+00	-11.7
42	23.9	119.	41.8	0.000E+00	0.000E+00	0.852
43	-12.0	89.6	-30.0	0.000E+00	0.000E+00	-26.0
44	-74.3	104.	-26.9	0.000E+00	0.000E+00	4.56
45	-15.5	117.	26.0	0.000E+00	0.000E+00	4.683E-15
46	-2.12	81.3	17.4	0.000E+00	0.000E+00	-2.71
47	-8.75	26.2	-6.06	0.000E+00	0.000E+00	1.29
48	-11.2	126.	-20.9	0.000E+00	0.000E+00	0.994
49	37.5	112.	-24.0	0.000E+00	0.000E+00	1.583E-14
50	-9.76	117.	-23.2	0.000E+00	0.000E+00	-8.30
51	37.5	112.	-24.0	0.000E+00	0.000E+00	-1.446E-14
52	39.0	116.	-23.0	0.000E+00	0.000E+00	-19.8
53	-9.76	117.	-23.2	0.000E+00	0.000E+00	-8.30
54	37.5	112.	-24.0	0.000E+00	0.000E+00	-1.289E-14
55	-15.5	117.	26.0	0.000E+00	0.000E+00	-1.878E-15
56	-2.12	81.3	17.4	0.000E+00	0.000E+00	-2.71
57	-11.2	126.	-20.9	0.000E+00	0.000E+00	0.994
58	-8.75	26.2	-6.06	0.000E+00	0.000E+00	1.29

59	39.0	116.	-23.0	0.000E+00	0.000E+00	-19.8
60	37.5	112.	-24.0	0.000E+00	0.000E+00	1.739E-14
61	53.1	96.8	44.3	0.000E+00	0.000E+00	-2.73
62	10.2	102.	29.8	0.000E+00	0.000E+00	-1.52
63	-27.9	66.5	1.98	0.000E+00	0.000E+00	-11.7
64	24.2	106.	36.9	0.000E+00	0.000E+00	0.737
65	23.9	119.	41.8	0.000E+00	0.000E+00	0.852
66	-12.0	89.6	-30.0	0.000E+00	0.000E+00	-26.0
67	-9.76	117.	-23.2	0.000E+00	0.000E+00	8.30
68	-74.3	104.	-26.9	0.000E+00	0.000E+00	-4.56
69	-12.0	89.6	-30.0	0.000E+00	0.000E+00	26.0
70	-74.3	104.	-26.9	0.000E+00	0.000E+00	4.56
71	39.0	116.	-23.0	0.000E+00	0.000E+00	19.8
72	-11.2	126.	-20.9	0.000E+00	0.000E+00	-0.994
73	-15.5	117.	26.0	0.000E+00	0.000E+00	4.939E-15
74	-2.12	81.3	17.4	0.000E+00	0.000E+00	2.71
75	-8.75	26.2	-6.06	0.000E+00	0.000E+00	-1.29
76	-39.7	106.	-26.2	0.000E+00	0.000E+00	-5.81
77	-17.3	99.8	-27.5	0.000E+00	0.000E+00	-18.8
78	19.2	118.	-22.6	0.000E+00	0.000E+00	-3.73
79	-15.5	66.1	6.52	0.000E+00	0.000E+00	-10.1
80	-11.2	117.	-23.0	0.000E+00	0.000E+00	-5.72
81	3.42	92.9	23.9	0.000E+00	0.000E+00	-4.59
82	8.38	95.3	26.7	0.000E+00	0.000E+00	1.62
83	58.0	105.	49.4	0.000E+00	0.000E+00	-2.78
84	58.0	105.	49.4	0.000E+00	0.000E+00	2.78
85	-27.9	66.5	1.98	0.000E+00	0.000E+00	11.7
86	23.9	119.	41.8	0.000E+00	0.000E+00	-0.852
87	3.42	92.9	23.9	0.000E+00	0.000E+00	4.59
88	8.38	95.3	26.7	0.000E+00	0.000E+00	-1.62
89	-15.5	66.1	6.52	0.000E+00	0.000E+00	10.1
90	24.2	106.	36.9	0.000E+00	0.000E+00	-0.737
91	10.2	102.	29.8	0.000E+00	0.000E+00	1.52
92	53.1	96.8	44.3	0.000E+00	0.000E+00	2.73
93	16.2	114.	-23.6	0.000E+00	0.000E+00	-4.016E-14
94	-9.26	24.5	-6.90	0.000E+00	0.000E+00	1.24
95	-11.3	121.	-22.2	0.000E+00	0.000E+00	0.590
96	-20.1	110.	21.6	0.000E+00	0.000E+00	6.640E-15
97	-20.1	110.	21.6	0.000E+00	0.000E+00	5.927E-15
98	-17.3	99.8	-27.5	0.000E+00	0.000E+00	18.8
99	-11.2	117.	-23.0	0.000E+00	0.000E+00	5.72
100	19.2	118.	-22.6	0.000E+00	0.000E+00	3.73
101	-9.26	24.5	-6.90	0.000E+00	0.000E+00	-1.24
102	-11.3	121.	-22.2	0.000E+00	0.000E+00	-0.590
103	-39.7	106.	-26.2	0.000E+00	0.000E+00	5.81
104	16.2	114.	-23.6	0.000E+00	0.000E+00	-2.327E-14

STRESS FORCE

NODE	X	Y	FX	FY	FZ
1	-3.8394E-04	-2.4289E-04	1.915	-44.57	0.0000E+00
2	-3.0053E-04	-3.0053E-04	16.65	-52.27	0.0000E+00
3	-2.4289E-04	-3.8394E-04	-8.023	-24.66	0.0000E+00
4	2.4289E-04	-3.8394E-04	8.023	-24.66	0.0000E+00
5	-2.5711E-04	-1.1606E-04	14.73	33.91	0.0000E+00
6	-1.9947E-04	-1.9947E-04	-16.87	52.66	0.0000E+00
7	-1.1606E-04	-2.5711E-04	-10.46	35.70	0.0000E+00
8	3.8394E-04	-2.4289E-04	-1.915	-44.57	0.0000E+00

9	3.0053E-04	-3.0053E-04	-16.65	-52.27	0.0000E+00
10	1.1606E-04	-2.5711E-04	10.46	35.70	0.0000E+00
11	0.0000E+00	-2.8209E-04	-4.7535E-06	53.08	0.0000E+00
12	-2.8209E-04	0.0000E+00	-5.002	1.8324E-07	0.0000E+00
13	2.5711E-04	-1.1606E-04	-14.73	33.91	0.0000E+00
14	1.9947E-04	-1.9947E-04	16.87	52.66	0.0000E+00
15	-2.5711E-04	1.1606E-04	14.73	-33.91	0.0000E+00
16	-1.9947E-04	1.9947E-04	-16.87	-52.66	0.0000E+00
17	2.8209E-04	0.0000E+00	5.002	-1.8324E-07	0.0000E+00
18	-3.8394E-04	2.4289E-04	1.915	44.57	0.0000E+00
19	-3.0053E-04	3.0053E-04	16.65	52.27	0.0000E+00
20	-1.1606E-04	2.5711E-04	-10.46	-35.70	0.0000E+00
21	0.0000E+00	2.8209E-04	4.7535E-06	-53.08	0.0000E+00
22	1.9947E-04	1.9947E-04	16.87	-52.66	0.0000E+00
23	1.1606E-04	2.5711E-04	10.46	-35.70	0.0000E+00
24	2.5711E-04	1.1606E-04	-14.73	-33.91	0.0000E+00
25	-2.4289E-04	3.8394E-04	-8.023	24.66	0.0000E+00
26	3.0053E-04	3.0053E-04	-16.65	52.27	0.0000E+00
27	2.4289E-04	3.8394E-04	8.023	24.66	0.0000E+00
28	3.8394E-04	2.4289E-04	-1.915	44.57	0.0000E+00

MACROSCOPIC STRESS FIELD

S(1,1) = 0.0000D+00 S(1,2) = 0.0000D+00 S(1,3) = 0.1000D+03
S(2,2) = 0.0000D+00 S(2,3) = 0.0000D+00
S(3,3) = 0.0000D+00

MACROSCOPIC STRAIN TENSOR

E(1,1) = -0.2436D-02 E(1,2) = -0.3604D-02 E(1,3) = 0.1113D-01
E(2,2) = 0.0000D+00 E(2,3) = 0.0000D+00
E(3,3) = 0.0000D+00

MICROSCOPIC STRESS FIELD

ELE	S11	S22	S33	S23	S13	S12
1	-6.35	-7.92	159.	0.000E+00	0.000E+00	6.210E-16
2	-19.8	-8.08	159.	0.000E+00	0.000E+00	-1.35
3	-26.4	-3.32	160.	0.000E+00	0.000E+00	-10.4
4	-21.8	-7.27	159.	0.000E+00	0.000E+00	-1.17
5	-16.2	-7.57	159.	0.000E+00	0.000E+00	-5.35
6	-0.415	-8.99	159.	0.000E+00	0.000E+00	-3.05
7	4.04	6.04	43.0	0.000E+00	0.000E+00	-1.22
8	-6.35	-7.92	159.	0.000E+00	0.000E+00	2.180E-15
9	-7.49	4.88	38.2	0.000E+00	0.000E+00	-3.102E-15
10	-7.49	4.88	38.2	0.000E+00	0.000E+00	-2.773E-15
11	-0.415	-8.99	159.	0.000E+00	0.000E+00	3.05
12	4.04	6.04	43.0	0.000E+00	0.000E+00	1.22
13	21.8	8.32	50.7	0.000E+00	0.000E+00	-1.03
14	-6.74	-5.77	34.4	0.000E+00	0.000E+00	-5.16
15	3.64	3.34	41.8	0.000E+00	0.000E+00	-7.50
16	-3.09	-1.62	37.4	0.000E+00	0.000E+00	-9.46

17	-6.04	-1.66	36.3	0.000E+00	0.000E+00	-5.74
18	-15.4	-7.85	30.4	0.000E+00	0.000E+00	-7.24
19	-10.9	-5.67	32.9	0.000E+00	0.000E+00	-4.68
20	4.68	4.18	42.6	0.000E+00	0.000E+00	-1.38
21	-21.8	-7.27	159.	0.000E+00	0.000E+00	1.17
22	-19.8	-8.08	159.	0.000E+00	0.000E+00	1.35
23	-26.4	-3.32	160.	0.000E+00	0.000E+00	10.4
24	-16.2	-7.57	159.	0.000E+00	0.000E+00	5.35
25	-10.9	-5.67	32.9	0.000E+00	0.000E+00	4.68
26	4.68	4.18	42.6	0.000E+00	0.000E+00	1.38
27	18.0	2.20	46.9	0.000E+00	0.000E+00	-1.10
28	18.0	2.20	46.9	0.000E+00	0.000E+00	1.10
29	-6.04	-1.66	36.3	0.000E+00	0.000E+00	5.74
30	-8.771E-02	4.38	40.8	0.000E+00	0.000E+00	-0.554
31	-3.45	3.12	39.1	0.000E+00	0.000E+00	-6.081E-16
32	-7.21	-9.31	159.	0.000E+00	0.000E+00	-1.40
33	-4.08	0.998	38.0	0.000E+00	0.000E+00	-1.49
34	-5.38	-7.19	160.	0.000E+00	0.000E+00	-6.67
35	-14.5	-6.56	160.	0.000E+00	0.000E+00	-2.85
36	-17.7	-7.97	159.	0.000E+00	0.000E+00	-0.904
37	-35.3	-4.77	160.	0.000E+00	0.000E+00	-5.70
38	21.8	8.32	50.7	0.000E+00	0.000E+00	1.03
39	3.64	3.34	41.8	0.000E+00	0.000E+00	7.50
40	-6.74	-5.77	34.4	0.000E+00	0.000E+00	5.16
41	-15.4	-7.85	30.4	0.000E+00	0.000E+00	7.24
42	-3.09	-1.62	37.4	0.000E+00	0.000E+00	9.46
43	-14.5	-6.56	160.	0.000E+00	0.000E+00	2.85
44	-35.3	-4.77	160.	0.000E+00	0.000E+00	5.70
45	-3.45	3.12	39.1	0.000E+00	0.000E+00	1.817E-15
46	-8.771E-02	4.38	40.8	0.000E+00	0.000E+00	0.554
47	-4.08	0.998	38.0	0.000E+00	0.000E+00	1.49
48	-7.21	-9.31	159.	0.000E+00	0.000E+00	1.40
49	-6.02	-7.95	159.	0.000E+00	0.000E+00	8.172E-15
50	-17.7	-7.97	159.	0.000E+00	0.000E+00	0.904
51	-6.02	-7.95	159.	0.000E+00	0.000E+00	-6.442E-15
52	-5.38	-7.19	160.	0.000E+00	0.000E+00	6.67
53	-17.7	-7.97	159.	0.000E+00	0.000E+00	0.904
54	-6.02	-7.95	159.	0.000E+00	0.000E+00	-6.154E-15
55	-3.45	3.12	39.1	0.000E+00	0.000E+00	-5.725E-16
56	-8.771E-02	4.38	40.8	0.000E+00	0.000E+00	0.554
57	-7.21	-9.31	159.	0.000E+00	0.000E+00	1.40
58	-4.08	0.998	38.0	0.000E+00	0.000E+00	1.49
59	-5.38	-7.19	160.	0.000E+00	0.000E+00	6.67
60	-6.02	-7.95	159.	0.000E+00	0.000E+00	8.460E-15
61	21.8	8.32	50.7	0.000E+00	0.000E+00	1.03
62	-6.74	-5.77	34.4	0.000E+00	0.000E+00	5.16
63	-15.4	-7.85	30.4	0.000E+00	0.000E+00	7.24
64	3.64	3.34	41.8	0.000E+00	0.000E+00	7.50
65	-3.09	-1.62	37.4	0.000E+00	0.000E+00	9.46
66	-14.5	-6.56	160.	0.000E+00	0.000E+00	2.85
67	-17.7	-7.97	159.	0.000E+00	0.000E+00	-0.904
68	-35.3	-4.77	160.	0.000E+00	0.000E+00	-5.70
69	-14.5	-6.56	160.	0.000E+00	0.000E+00	-2.85
70	-35.3	-4.77	160.	0.000E+00	0.000E+00	5.70
71	-5.38	-7.19	160.	0.000E+00	0.000E+00	-6.67
72	-7.21	-9.31	159.	0.000E+00	0.000E+00	-1.40
73	-3.45	3.12	39.1	0.000E+00	0.000E+00	1.852E-15
74	-8.771E-02	4.38	40.8	0.000E+00	0.000E+00	-0.554
75	-4.08	0.998	38.0	0.000E+00	0.000E+00	-1.49
76	-26.4	-3.32	160.	0.000E+00	0.000E+00	10.4

77	-21.8	-7.27	159.	0.000E+00	0.000E+00	1.17
78	-16.2	-7.57	159.	0.000E+00	0.000E+00	5.35
79	-6.04	-1.66	36.3	0.000E+00	0.000E+00	5.74
80	-19.8	-8.08	159.	0.000E+00	0.000E+00	1.35
81	-10.9	-5.67	32.9	0.000E+00	0.000E+00	4.68
82	4.68	4.18	42.6	0.000E+00	0.000E+00	1.38
83	18.0	2.20	46.9	0.000E+00	0.000E+00	1.10
84	18.0	2.20	46.9	0.000E+00	0.000E+00	-1.10
85	-15.4	-7.85	30.4	0.000E+00	0.000E+00	-7.24
86	-3.09	-1.62	37.4	0.000E+00	0.000E+00	-9.46
87	-10.9	-5.67	32.9	0.000E+00	0.000E+00	-4.68
88	4.68	4.18	42.6	0.000E+00	0.000E+00	-1.38
89	-6.04	-1.66	36.3	0.000E+00	0.000E+00	-5.74
90	3.64	3.34	41.8	0.000E+00	0.000E+00	-7.50
91	-6.74	-5.77	34.4	0.000E+00	0.000E+00	-5.16
92	21.8	8.32	50.7	0.000E+00	0.000E+00	-1.03
93	-6.35	-7.92	159.	0.000E+00	0.000E+00	-1.578E-14
94	4.04	6.04	43.0	0.000E+00	0.000E+00	1.22
95	-0.415	-8.99	159.	0.000E+00	0.000E+00	3.05
96	-7.49	4.88	38.2	0.000E+00	0.000E+00	1.828E-15
97	-7.49	4.88	38.2	0.000E+00	0.000E+00	2.157E-15
98	-21.8	-7.27	159.	0.000E+00	0.000E+00	-1.17
99	-19.8	-8.08	159.	0.000E+00	0.000E+00	-1.35
100	-16.2	-7.57	159.	0.000E+00	0.000E+00	-5.35
101	4.04	6.04	43.0	0.000E+00	0.000E+00	-1.22
102	-0.415	-8.99	159.	0.000E+00	0.000E+00	-3.05
103	-26.4	-3.32	160.	0.000E+00	0.000E+00	-10.4
104	-6.35	-7.92	159.	0.000E+00	0.000E+00	-1.422E-14

STRESS FORCE

NODE	X	Y	FX	FY	FZ
1	-3.8394E-04	-2.4289E-04	6.099	6.485	0.0000E+00
2	-3.0053E-04	-3.0053E-04	10.16	2.168	0.0000E+00
3	-2.4289E-04	-3.8394E-04	7.597	4.298	0.0000E+00
4	2.4289E-04	-3.8394E-04	-7.597	4.298	0.0000E+00
5	-2.5711E-04	-1.1606E-04	-2.000	-5.050	0.0000E+00
6	-1.9947E-04	-1.9947E-04	-10.20	-2.176	0.0000E+00
7	-1.1606E-04	-2.5711E-04	-10.68	-4.417	0.0000E+00
8	3.8394E-04	-2.4289E-04	-6.099	6.485	0.0000E+00
9	3.0053E-04	-3.0053E-04	-10.16	2.168	0.0000E+00
10	1.1606E-04	-2.5711E-04	10.68	-4.417	0.0000E+00
11	0.0000E+00	-2.8209E-04	-2.1422E-06	0.4535	0.0000E+00
12	-2.8209E-04	0.0000E+00	-2.839	-3.7359E-08	0.0000E+00
13	2.5711E-04	-1.1606E-04	2.000	-5.050	0.0000E+00
14	1.9947E-04	-1.9947E-04	10.20	-2.176	0.0000E+00
15	-2.5711E-04	1.1606E-04	-2.000	5.050	0.0000E+00
16	-1.9947E-04	1.9947E-04	-10.20	2.176	0.0000E+00
17	2.8209E-04	0.0000E+00	2.839	3.7359E-08	0.0000E+00
18	-3.8394E-04	2.4289E-04	6.099	-6.485	0.0000E+00
19	-3.0053E-04	3.0053E-04	10.16	-2.168	0.0000E+00
20	-1.1606E-04	2.5711E-04	-10.68	4.417	0.0000E+00
21	0.0000E+00	2.8209E-04	2.1422E-06	-0.4535	0.0000E+00
22	1.9947E-04	1.9947E-04	10.20	2.176	0.0000E+00
23	1.1606E-04	2.5711E-04	10.68	4.417	0.0000E+00
24	2.5711E-04	1.1606E-04	2.000	5.050	0.0000E+00
25	-2.4289E-04	3.8394E-04	7.597	-4.298	0.0000E+00
26	3.0053E-04	3.0053E-04	-10.16	-2.168	0.0000E+00

27	2.4289E-04	3.8394E-04	-7.597	-4.298	0.0000E+00
28	3.8394E-04	2.4289E-04	-6.099	-6.485	0.0000E+00

MACROSCOPIC STRESS FIELD

S(1,1) = 0.0000D+00   S(1,2) = 0.0000D+00   S(1,3) = 0.0000D+00
S(2,2) = 0.1000D+03   S(2,3) = 0.0000D+00
S(3,3) = 0.0000D+00

MACROSCOPIC STRAIN TENSOR

E(1,1) = 0.0000D+00   E(1,2) = 0.0000D+00   E(1,3) = 0.0000D+00
E(2,2) = 0.2880D-01   E(2,3) = 0.0000D+00
E(3,3) = 0.0000D+00

MICROSCOPIC STRESS FIELD

ELE	S11	S22	S33	S23	S13	S12
1	0.000E+00	0.000E+00	0.000E+00	140.	3.422E-04	0.000E+00
2	0.000E+00	0.000E+00	0.000E+00	146.	12.0	0.000E+00
3	0.000E+00	0.000E+00	0.000E+00	119.	24.8	0.000E+00
4	0.000E+00	0.000E+00	0.000E+00	117.	27.9	0.000E+00
5	0.000E+00	0.000E+00	0.000E+00	144.	24.4	0.000E+00
6	0.000E+00	0.000E+00	0.000E+00	157.	1.433E-04	0.000E+00
7	0.000E+00	0.000E+00	0.000E+00	10.0	2.677E-05	0.000E+00
8	0.000E+00	0.000E+00	0.000E+00	140.	-3.229E-04	0.000E+00
9	0.000E+00	0.000E+00	0.000E+00	70.9	1.777E-05	0.000E+00
10	0.000E+00	0.000E+00	0.000E+00	70.9	-1.599E-05	0.000E+00
11	0.000E+00	0.000E+00	0.000E+00	157.	-1.386E-04	0.000E+00
12	0.000E+00	0.000E+00	0.000E+00	10.0	-2.960E-05	0.000E+00
13	0.000E+00	0.000E+00	0.000E+00	76.3	15.6	0.000E+00
14	0.000E+00	0.000E+00	0.000E+00	88.4	29.6	0.000E+00
15	0.000E+00	0.000E+00	0.000E+00	72.3	45.7	0.000E+00
16	0.000E+00	0.000E+00	0.000E+00	87.9	56.5	0.000E+00
17	0.000E+00	0.000E+00	0.000E+00	53.3	64.7	0.000E+00
18	0.000E+00	0.000E+00	0.000E+00	64.1	80.3	0.000E+00
19	0.000E+00	0.000E+00	0.000E+00	67.9	50.1	0.000E+00
20	0.000E+00	0.000E+00	0.000E+00	66.5	4.34	0.000E+00
21	0.000E+00	0.000E+00	0.000E+00	117.	-28.0	0.000E+00
22	0.000E+00	0.000E+00	0.000E+00	146.	-12.0	0.000E+00
23	0.000E+00	0.000E+00	0.000E+00	119.	-24.8	0.000E+00
24	0.000E+00	0.000E+00	0.000E+00	144.	-24.4	0.000E+00
25	0.000E+00	0.000E+00	0.000E+00	67.9	-50.1	0.000E+00
26	0.000E+00	0.000E+00	0.000E+00	66.5	-4.34	0.000E+00
27	0.000E+00	0.000E+00	0.000E+00	76.3	15.6	0.000E+00
28	0.000E+00	0.000E+00	0.000E+00	76.3	-15.6	0.000E+00
29	0.000E+00	0.000E+00	0.000E+00	53.3	-64.7	0.000E+00
30	0.000E+00	0.000E+00	0.000E+00	42.6	28.3	0.000E+00
31	0.000E+00	0.000E+00	0.000E+00	70.9	1.196E-05	0.000E+00
32	0.000E+00	0.000E+00	0.000E+00	157.	2.557E-05	0.000E+00
33	0.000E+00	0.000E+00	0.000E+00	10.0	1.891E-05	0.000E+00
34	0.000E+00	0.000E+00	0.000E+00	144.	24.4	0.000E+00

35	0.000E+00	0.000E+00	0.000E+00	117.	27.9	0.000E+00
36	0.000E+00	0.000E+00	0.000E+00	146.	12.0	0.000E+00
37	0.000E+00	0.000E+00	0.000E+00	119.	24.8	0.000E+00
38	0.000E+00	0.000E+00	0.000E+00	76.3	-15.6	0.000E+00
39	0.000E+00	0.000E+00	0.000E+00	72.3	-45.7	0.000E+00
40	0.000E+00	0.000E+00	0.000E+00	88.4	-29.6	0.000E+00
41	0.000E+00	0.000E+00	0.000E+00	64.1	-80.3	0.000E+00
42	0.000E+00	0.000E+00	0.000E+00	87.9	-56.5	0.000E+00
43	0.000E+00	0.000E+00	0.000E+00	117.	-27.9	0.000E+00
44	0.000E+00	0.000E+00	0.000E+00	119.	-24.8	0.000E+00
45	0.000E+00	0.000E+00	0.000E+00	70.9	1.196E-05	0.000E+00
46	0.000E+00	0.000E+00	0.000E+00	42.6	-28.3	0.000E+00
47	0.000E+00	0.000E+00	0.000E+00	10.0	1.891E-05	0.000E+00
48	0.000E+00	0.000E+00	0.000E+00	157.	2.557E-05	0.000E+00
49	0.000E+00	0.000E+00	0.000E+00	140.	-2.326E-05	0.000E+00
50	0.000E+00	0.000E+00	0.000E+00	146.	-12.0	0.000E+00
51	0.000E+00	0.000E+00	0.000E+00	140.	-2.326E-05	0.000E+00
52	0.000E+00	0.000E+00	0.000E+00	144.	-24.4	0.000E+00
53	0.000E+00	0.000E+00	0.000E+00	146.	-12.0	0.000E+00
54	0.000E+00	0.000E+00	0.000E+00	140.	-4.732E-05	0.000E+00
55	0.000E+00	0.000E+00	0.000E+00	70.9	-1.082E-05	0.000E+00
56	0.000E+00	0.000E+00	0.000E+00	42.6	-28.3	0.000E+00
57	0.000E+00	0.000E+00	0.000E+00	157.	-3.719E-05	0.000E+00
58	0.000E+00	0.000E+00	0.000E+00	10.0	-1.648E-05	0.000E+00
59	0.000E+00	0.000E+00	0.000E+00	144.	-24.4	0.000E+00
60	0.000E+00	0.000E+00	0.000E+00	140.	-4.732E-05	0.000E+00
61	0.000E+00	0.000E+00	0.000E+00	76.3	-15.6	0.000E+00
62	0.000E+00	0.000E+00	0.000E+00	88.4	-29.6	0.000E+00
63	0.000E+00	0.000E+00	0.000E+00	64.1	-80.3	0.000E+00
64	0.000E+00	0.000E+00	0.000E+00	72.3	-45.7	0.000E+00
65	0.000E+00	0.000E+00	0.000E+00	87.9	-56.5	0.000E+00
66	0.000E+00	0.000E+00	0.000E+00	117.	-27.9	0.000E+00
67	0.000E+00	0.000E+00	0.000E+00	146.	12.0	0.000E+00
68	0.000E+00	0.000E+00	0.000E+00	119.	24.8	0.000E+00
69	0.000E+00	0.000E+00	0.000E+00	117.	27.9	0.000E+00
70	0.000E+00	0.000E+00	0.000E+00	119.	-24.8	0.000E+00
71	0.000E+00	0.000E+00	0.000E+00	144.	24.4	0.000E+00
72	0.000E+00	0.000E+00	0.000E+00	157.	-3.719E-05	0.000E+00
73	0.000E+00	0.000E+00	0.000E+00	70.9	-1.082E-05	0.000E+00
74	0.000E+00	0.000E+00	0.000E+00	42.6	28.3	0.000E+00
75	0.000E+00	0.000E+00	0.000E+00	10.0	-1.648E-05	0.000E+00
76	0.000E+00	0.000E+00	0.000E+00	119.	-24.8	0.000E+00
77	0.000E+00	0.000E+00	0.000E+00	117.	-27.9	0.000E+00
78	0.000E+00	0.000E+00	0.000E+00	144.	-24.4	0.000E+00
79	0.000E+00	0.000E+00	0.000E+00	53.3	-64.7	0.000E+00
80	0.000E+00	0.000E+00	0.000E+00	146.	-12.0	0.000E+00
81	0.000E+00	0.000E+00	0.000E+00	67.9	-50.1	0.000E+00
82	0.000E+00	0.000E+00	0.000E+00	66.5	-4.34	0.000E+00
83	0.000E+00	0.000E+00	0.000E+00	76.3	-15.6	0.000E+00
84	0.000E+00	0.000E+00	0.000E+00	76.3	15.6	0.000E+00
85	0.000E+00	0.000E+00	0.000E+00	64.1	80.3	0.000E+00
86	0.000E+00	0.000E+00	0.000E+00	87.9	56.5	0.000E+00
87	0.000E+00	0.000E+00	0.000E+00	67.9	50.1	0.000E+00
88	0.000E+00	0.000E+00	0.000E+00	66.5	4.34	0.000E+00
89	0.000E+00	0.000E+00	0.000E+00	53.3	64.7	0.000E+00
90	0.000E+00	0.000E+00	0.000E+00	72.3	45.7	0.000E+00
91	0.000E+00	0.000E+00	0.000E+00	88.4	29.6	0.000E+00
92	0.000E+00	0.000E+00	0.000E+00	76.3	15.6	0.000E+00
93	0.000E+00	0.000E+00	0.000E+00	140.	3.422E-04	0.000E+00
94	0.000E+00	0.000E+00	0.000E+00	10.0	2.677E-05	0.000E+00

95	0.000E+00	0.000E+00	0.000E+00	157.	1.433E-04	0.000E+00
96	0.000E+00	0.000E+00	0.000E+00	70.9	1.777E-05	0.000E+00
97	0.000E+00	0.000E+00	0.000E+00	70.9	-1.599E-05	0.000E+00
98	0.000E+00	0.000E+00	0.000E+00	117.	27.9	0.000E+00
99	0.000E+00	0.000E+00	0.000E+00	146.	12.0	0.000E+00
100	0.000E+00	0.000E+00	0.000E+00	144.	24.4	0.000E+00
101	0.000E+00	0.000E+00	0.000E+00	10.0	-2.960E-05	0.000E+00
102	0.000E+00	0.000E+00	0.000E+00	157.	-1.386E-04	0.000E+00
103	0.000E+00	0.000E+00	0.000E+00	119.	24.8	0.000E+00
104	0.000E+00	0.000E+00	0.000E+00	140.	-3.229E-04	0.000E+00

STRESS FORCE

NODE	X	Y	FX	FY	FZ
1	-3.8394E-04	-2.4289E-04	0.0000E+00	0.0000E+00	-57.43
2	-3.0053E-04	-3.0053E-04	0.0000E+00	0.0000E+00	-63.63
3	-2.4289E-04	-3.8394E-04	0.0000E+00	0.0000E+00	-42.25
4	2.4289E-04	-3.8394E-04	0.0000E+00	0.0000E+00	-42.25
5	-2.5711E-04	-1.1606E-04	0.0000E+00	0.0000E+00	42.25
6	-1.9947E-04	-1.9947E-04	0.0000E+00	0.0000E+00	63.63
7	-1.1606E-04	-2.5711E-04	0.0000E+00	0.0000E+00	57.43
8	3.8394E-04	-2.4289E-04	0.0000E+00	0.0000E+00	-57.43
9	3.0053E-04	-3.0053E-04	0.0000E+00	0.0000E+00	-63.63
10	1.1606E-04	-2.5711E-04	0.0000E+00	0.0000E+00	57.43
11	0.0000E+00	-2.8209E-04	0.0000E+00	0.0000E+00	46.12
12	-2.8209E-04	0.0000E+00	0.0000E+00	0.0000E+00	2.3485E-05
13	2.5711E-04	-1.1606E-04	0.0000E+00	0.0000E+00	42.25
14	1.9947E-04	-1.9947E-04	0.0000E+00	0.0000E+00	63.63
15	-2.5711E-04	1.1606E-04	0.0000E+00	0.0000E+00	-42.25
16	-1.9947E-04	1.9947E-04	0.0000E+00	0.0000E+00	-63.63
17	2.8209E-04	0.0000E+00	0.0000E+00	0.0000E+00	2.5640E-05
18	-3.8394E-04	2.4289E-04	0.0000E+00	0.0000E+00	57.43
19	-3.0053E-04	3.0053E-04	0.0000E+00	0.0000E+00	63.63
20	-1.1606E-04	2.5711E-04	0.0000E+00	0.0000E+00	-57.43
21	0.0000E+00	2.8209E-04	0.0000E+00	0.0000E+00	-46.12
22	1.9947E-04	1.9947E-04	0.0000E+00	0.0000E+00	-63.63
23	1.1606E-04	2.5711E-04	0.0000E+00	0.0000E+00	-57.43
24	2.5711E-04	1.1606E-04	0.0000E+00	0.0000E+00	-42.25
25	-2.4289E-04	3.8394E-04	0.0000E+00	0.0000E+00	42.25
26	3.0053E-04	3.0053E-04	0.0000E+00	0.0000E+00	63.63
27	2.4289E-04	3.8394E-04	0.0000E+00	0.0000E+00	42.25
28	3.8394E-04	2.4289E-04	0.0000E+00	0.0000E+00	57.43

MACROSCOPIC STRESS FIELD

S(1,1) =	0.0000D+00	S(1,2) =	0.0000D+00	S(1,3) =	0.0000D+00
		S(2,2) =	0.0000D+00	S(2,3) =	0.1000D+03
				S(3,3) =	0.0000D+00

MACROSCOPIC STRAIN TENSOR

E(1,1) =	0.0000D+00	E(1,2) =	0.0000D+00	E(1,3) =	0.0000D+00

E(2,2) = 0.0000D+00 E(2,3) = 0.2655D-01
E(3,3) = 0.0000D+00

MICROSCOPIC STRESS FIELD

ELE	S11	S22	S33	S23	S13	S12
1	0.000E+00	0.000E+00	0.000E+00	-4.863E-05	128.	0.000E+00
2	0.000E+00	0.000E+00	0.000E+00	11.6	150.	0.000E+00
3	0.000E+00	0.000E+00	0.000E+00	-2.276E-05	176.	0.000E+00
4	0.000E+00	0.000E+00	0.000E+00	14.5	148.	0.000E+00
5	0.000E+00	0.000E+00	0.000E+00	16.4	119.	0.000E+00
6	0.000E+00	0.000E+00	0.000E+00	19.1	114.	0.000E+00
7	0.000E+00	0.000E+00	0.000E+00	16.6	75.3	0.000E+00
8	0.000E+00	0.000E+00	0.000E+00	-4.863E-05	128.	0.000E+00
9	0.000E+00	0.000E+00	0.000E+00	-1.410E-06	69.5	0.000E+00
10	0.000E+00	0.000E+00	0.000E+00	-1.410E-06	69.5	0.000E+00
11	0.000E+00	0.000E+00	0.000E+00	-19.1	114.	0.000E+00
12	0.000E+00	0.000E+00	0.000E+00	-16.6	75.3	0.000E+00
13	0.000E+00	0.000E+00	0.000E+00	8.165E-06	5.90	0.000E+00
14	0.000E+00	0.000E+00	0.000E+00	52.4	66.3	0.000E+00
15	0.000E+00	0.000E+00	0.000E+00	67.6	51.1	0.000E+00
16	0.000E+00	0.000E+00	0.000E+00	84.2	62.6	0.000E+00
17	0.000E+00	0.000E+00	0.000E+00	47.5	71.2	0.000E+00
18	0.000E+00	0.000E+00	0.000E+00	59.0	87.8	0.000E+00
19	0.000E+00	0.000E+00	0.000E+00	30.9	87.8	0.000E+00
20	0.000E+00	0.000E+00	0.000E+00	29.5	40.0	0.000E+00
21	0.000E+00	0.000E+00	0.000E+00	-14.5	148.	0.000E+00
22	0.000E+00	0.000E+00	0.000E+00	-11.6	150.	0.000E+00
23	0.000E+00	0.000E+00	0.000E+00	-2.276E-05	176.	0.000E+00
24	0.000E+00	0.000E+00	0.000E+00	-16.4	119.	0.000E+00
25	0.000E+00	0.000E+00	0.000E+00	-30.9	87.8	0.000E+00
26	0.000E+00	0.000E+00	0.000E+00	-29.5	40.0	0.000E+00
27	0.000E+00	0.000E+00	0.000E+00	-2.061E-06	5.90	0.000E+00
28	0.000E+00	0.000E+00	0.000E+00	-2.061E-06	5.90	0.000E+00
29	0.000E+00	0.000E+00	0.000E+00	-47.5	71.2	0.000E+00
30	0.000E+00	0.000E+00	0.000E+00	4.61	64.9	0.000E+00
31	0.000E+00	0.000E+00	0.000E+00	9.762E-06	69.5	0.000E+00
32	0.000E+00	0.000E+00	0.000E+00	19.1	114.	0.000E+00
33	0.000E+00	0.000E+00	0.000E+00	16.6	75.3	0.000E+00
34	0.000E+00	0.000E+00	0.000E+00	16.4	119.	0.000E+00
35	0.000E+00	0.000E+00	0.000E+00	14.5	148.	0.000E+00
36	0.000E+00	0.000E+00	0.000E+00	11.6	150.	0.000E+00
37	0.000E+00	0.000E+00	0.000E+00	4.185E-06	176.	0.000E+00
38	0.000E+00	0.000E+00	0.000E+00	8.165E-06	5.90	0.000E+00
39	0.000E+00	0.000E+00	0.000E+00	-67.6	51.1	0.000E+00
40	0.000E+00	0.000E+00	0.000E+00	-52.4	66.3	0.000E+00
41	0.000E+00	0.000E+00	0.000E+00	-59.0	87.8	0.000E+00
42	0.000E+00	0.000E+00	0.000E+00	-84.2	62.6	0.000E+00
43	0.000E+00	0.000E+00	0.000E+00	-14.5	148.	0.000E+00
44	0.000E+00	0.000E+00	0.000E+00	4.185E-06	176.	0.000E+00
45	0.000E+00	0.000E+00	0.000E+00	-7.915E-06	69.5	0.000E+00
46	0.000E+00	0.000E+00	0.000E+00	-4.61	64.9	0.000E+00
47	0.000E+00	0.000E+00	0.000E+00	-16.6	75.3	0.000E+00
48	0.000E+00	0.000E+00	0.000E+00	-19.1	114.	0.000E+00
49	0.000E+00	0.000E+00	0.000E+00	7.838E-05	128.	0.000E+00
50	0.000E+00	0.000E+00	0.000E+00	-11.6	150.	0.000E+00
51	0.000E+00	0.000E+00	0.000E+00	4.557E-05	128.	0.000E+00
52	0.000E+00	0.000E+00	0.000E+00	-16.4	119.	0.000E+00

53	0.000E+00	0.000E+00	0.000E+00	-11.6	150.	0.000E+00
54	0.000E+00	0.000E+00	0.000E+00	4.557E-05	128.	0.000E+00
55	0.000E+00	0.000E+00	0.000E+00	9.762E-06	69.5	0.000E+00
56	0.000E+00	0.000E+00	0.000E+00	-4.61	64.9	0.000E+00
57	0.000E+00	0.000E+00	0.000E+00	-19.1	114.	0.000E+00
58	0.000E+00	0.000E+00	0.000E+00	-16.6	75.3	0.000E+00
59	0.000E+00	0.000E+00	0.000E+00	-16.4	119.	0.000E+00
60	0.000E+00	0.000E+00	0.000E+00	7.838E-05	128.	0.000E+00
61	0.000E+00	0.000E+00	0.000E+00	-1.304E-05	5.90	0.000E+00
62	0.000E+00	0.000E+00	0.000E+00	-52.4	66.3	0.000E+00
63	0.000E+00	0.000E+00	0.000E+00	-59.0	87.8	0.000E+00
64	0.000E+00	0.000E+00	0.000E+00	-67.6	51.1	0.000E+00
65	0.000E+00	0.000E+00	0.000E+00	-84.2	62.6	0.000E+00
66	0.000E+00	0.000E+00	0.000E+00	-14.5	148.	0.000E+00
67	0.000E+00	0.000E+00	0.000E+00	11.6	150.	0.000E+00
68	0.000E+00	0.000E+00	0.000E+00	4.256E-05	176.	0.000E+00
69	0.000E+00	0.000E+00	0.000E+00	14.5	148.	0.000E+00
70	0.000E+00	0.000E+00	0.000E+00	4.256E-05	176.	0.000E+00
71	0.000E+00	0.000E+00	0.000E+00	16.4	119.	0.000E+00
72	0.000E+00	0.000E+00	0.000E+00	19.1	114.	0.000E+00
73	0.000E+00	0.000E+00	0.000E+00	-7.915E-06	69.5	0.000E+00
74	0.000E+00	0.000E+00	0.000E+00	4.61	64.9	0.000E+00
75	0.000E+00	0.000E+00	0.000E+00	16.6	75.3	0.000E+00
76	0.000E+00	0.000E+00	0.000E+00	2.883E-05	176.	0.000E+00
77	0.000E+00	0.000E+00	0.000E+00	-14.5	148.	0.000E+00
78	0.000E+00	0.000E+00	0.000E+00	-16.4	119.	0.000E+00
79	0.000E+00	0.000E+00	0.000E+00	-47.5	71.2	0.000E+00
80	0.000E+00	0.000E+00	0.000E+00	-11.6	150.	0.000E+00
81	0.000E+00	0.000E+00	0.000E+00	-30.9	87.8	0.000E+00
82	0.000E+00	0.000E+00	0.000E+00	-29.5	40.0	0.000E+00
83	0.000E+00	0.000E+00	0.000E+00	-3.313E-06	5.90	0.000E+00
84	0.000E+00	0.000E+00	0.000E+00	-3.313E-06	5.90	0.000E+00
85	0.000E+00	0.000E+00	0.000E+00	59.0	87.8	0.000E+00
86	0.000E+00	0.000E+00	0.000E+00	84.2	62.6	0.000E+00
87	0.000E+00	0.000E+00	0.000E+00	30.9	87.8	0.000E+00
88	0.000E+00	0.000E+00	0.000E+00	29.5	40.0	0.000E+00
89	0.000E+00	0.000E+00	0.000E+00	47.5	71.2	0.000E+00
90	0.000E+00	0.000E+00	0.000E+00	67.6	51.1	0.000E+00
91	0.000E+00	0.000E+00	0.000E+00	52.4	66.3	0.000E+00
92	0.000E+00	0.000E+00	0.000E+00	-1.304E-05	5.90	0.000E+00
93	0.000E+00	0.000E+00	0.000E+00	7.928E-05	128.	0.000E+00
94	0.000E+00	0.000E+00	0.000E+00	-16.6	75.3	0.000E+00
95	0.000E+00	0.000E+00	0.000E+00	-19.1	114.	0.000E+00
96	0.000E+00	0.000E+00	0.000E+00	-7.308E-06	69.5	0.000E+00
97	0.000E+00	0.000E+00	0.000E+00	-7.308E-06	69.5	0.000E+00
98	0.000E+00	0.000E+00	0.000E+00	14.5	148.	0.000E+00
99	0.000E+00	0.000E+00	0.000E+00	11.6	150.	0.000E+00
100	0.000E+00	0.000E+00	0.000E+00	16.4	119.	0.000E+00
101	0.000E+00	0.000E+00	0.000E+00	16.6	75.3	0.000E+00
102	0.000E+00	0.000E+00	0.000E+00	19.1	114.	0.000E+00
103	0.000E+00	0.000E+00	0.000E+00	2.883E-05	176.	0.000E+00
104	0.000E+00	0.000E+00	0.000E+00	7.928E-05	128.	0.000E+00

STRESS FORCE

NODE	X	Y	FX	FY	FZ
1	-3.8394E-04	-2.4289E-04	0.0000E+00	0.0000E+00	-43.23
2	-3.0053E-04	-3.0053E-04	0.0000E+00	0.0000E+00	-65.24

3	-2.4289E-04	-3.8394E-04	0.0000E+00	0.0000E+00	-57.69
4	2.4289E-04	-3.8394E-04	0.0000E+00	0.0000E+00	57.69
5	-2.5711E-04	-1.1606E-04	0.0000E+00	0.0000E+00	57.69
6	-1.9947E-04	-1.9947E-04	0.0000E+00	0.0000E+00	65.24
7	-1.1606E-04	-2.5711E-04	0.0000E+00	0.0000E+00	43.23
8	3.8394E-04	-2.4289E-04	0.0000E+00	0.0000E+00	43.23
9	3.0053E-04	-3.0053E-04	0.0000E+00	0.0000E+00	65.24
10	1.1606E-04	-2.5711E-04	0.0000E+00	0.0000E+00	-43.23
11	0.0000E+00	-2.8209E-04	0.0000E+00	0.0000E+00	1.1998E-05
12	-2.8209E-04	0.0000E+00	0.0000E+00	0.0000E+00	46.19
13	2.5711E-04	-1.1606E-04	0.0000E+00	0.0000E+00	-57.69
14	1.9947E-04	-1.9947E-04	0.0000E+00	0.0000E+00	-65.24
15	-2.5711E-04	1.1606E-04	0.0000E+00	0.0000E+00	57.69
16	-1.9947E-04	1.9947E-04	0.0000E+00	0.0000E+00	65.24
17	2.8209E-04	0.0000E+00	0.0000E+00	0.0000E+00	-46.19
18	-3.8394E-04	2.4289E-04	0.0000E+00	0.0000E+00	-43.23
19	-3.0053E-04	3.0053E-04	0.0000E+00	0.0000E+00	-65.24
20	-1.1606E-04	2.5711E-04	0.0000E+00	0.0000E+00	43.23
21	0.0000E+00	2.8209E-04	0.0000E+00	0.0000E+00	-2.8253E-05
22	1.9947E-04	1.9947E-04	0.0000E+00	0.0000E+00	-65.24
23	1.1606E-04	2.5711E-04	0.0000E+00	0.0000E+00	-43.23
24	2.5711E-04	1.1606E-04	0.0000E+00	0.0000E+00	-57.69
25	-2.4289E-04	3.8394E-04	0.0000E+00	0.0000E+00	-57.69
26	3.0053E-04	3.0053E-04	0.0000E+00	0.0000E+00	65.24
27	2.4289E-04	3.8394E-04	0.0000E+00	0.0000E+00	57.69
28	3.8394E-04	2.4289E-04	0.0000E+00	0.0000E+00	43.23

MACROSCOPIC STRESS FIELD

S(1,1) = 0.0000D+00	S(1,2) = 0.0000D+00	S(1,3) = 0.0000D+00
	S(2,2) = 0.0000D+00	S(2,3) = 0.0000D+00
		S(3,3) = 0.1000D+03

MACROSCOPIC STRAIN TENSOR

E(1,1) = 0.0000D+00	E(1,2) = 0.0000D+00	E(1,3) = 0.0000D+00
	E(2,2) = 0.0000D+00	E(2,3) = 0.0000D+00
		E(3,3) = 0.1786D-01

MICROSCOPIC STRESS FIELD

ELE	S11	S22	S33	S23	S13	S12
1	1.531E-13	-1.591E-14	-2.691E-15	0.000E+00	0.000E+00	157.
2	-32.0	15.0	3.48	0.000E+00	0.000E+00	191.
3	66.6	0.745	0.745	0.000E+00	0.000E+00	165.
4	113.	6.09	2.47	0.000E+00	0.000E+00	148.
5	28.4	20.5	5.36	0.000E+00	0.000E+00	149.
6	7.04	25.6	6.45	0.000E+00	0.000E+00	138.
7	35.1	57.3	35.1	0.000E+00	0.000E+00	46.4
8	-2.241E-13	-2.013E-14	-6.913E-15	0.000E+00	0.000E+00	157.
9	6.695E-15	3.112E-15	3.726E-15	0.000E+00	0.000E+00	25.2
10	-1.003E-14	-7.138E-15	-6.523E-15	0.000E+00	0.000E+00	25.2

11	-7.04	-25.6	-6.45	0.000E+00	0.000E+00	138.
12	-35.1	-57.3	-35.1	0.000E+00	0.000E+00	46.4
13	45.6	27.9	27.9	0.000E+00	0.000E+00	45.5
14	53.7	80.4	51.0	0.000E+00	0.000E+00	56.0
15	136.	145.	107.	0.000E+00	0.000E+00	38.4
16	160.	171.	126.	0.000E+00	0.000E+00	46.6
17	149.	141.	110.	0.000E+00	0.000E+00	38.2
18	177.	164.	130.	0.000E+00	0.000E+00	45.4
19	84.6	57.8	54.1	0.000E+00	0.000E+00	56.0
20	3.79	5.29	3.45	0.000E+00	0.000E+00	24.1
21	-113.	-6.09	-2.47	0.000E+00	0.000E+00	148.
22	32.0	-15.0	-3.48	0.000E+00	0.000E+00	191.
23	-66.6	-0.745	-0.745	0.000E+00	0.000E+00	165.
24	-28.4	-20.5	-5.36	0.000E+00	0.000E+00	149.
25	-84.6	-57.8	-54.1	0.000E+00	0.000E+00	56.0
26	-3.79	-5.29	-3.45	0.000E+00	0.000E+00	24.1
27	26.6	16.3	16.3	0.000E+00	0.000E+00	27.4
28	-26.6	-16.3	-16.3	0.000E+00	0.000E+00	27.4
29	-149.	-141.	-110.	0.000E+00	0.000E+00	38.2
30	5.72	6.92	4.80	0.000E+00	0.000E+00	24.2
31	3.469E-15	6.080E-15	3.629E-15	0.000E+00	0.000E+00	25.7
32	10.4	37.8	9.54	0.000E+00	0.000E+00	120.
33	27.8	45.3	27.8	0.000E+00	0.000E+00	30.3
34	-2.60	14.4	3.59	0.000E+00	0.000E+00	178.
35	68.1	-10.9	-2.16	0.000E+00	0.000E+00	174.
36	-20.1	13.1	3.11	0.000E+00	0.000E+00	188.
37	85.7	0.959	0.959	0.000E+00	0.000E+00	144.
38	-45.6	-27.9	-27.9	0.000E+00	0.000E+00	45.5
39	-136.	-145.	-107.	0.000E+00	0.000E+00	38.4
40	-53.7	-80.4	-51.0	0.000E+00	0.000E+00	56.0
41	-177.	-164.	-130.	0.000E+00	0.000E+00	45.4
42	-160.	-171.	-126.	0.000E+00	0.000E+00	46.6
43	-68.1	10.9	2.16	0.000E+00	0.000E+00	174.
44	-85.7	-0.959	-0.959	0.000E+00	0.000E+00	144.
45	1.866E-15	3.464E-15	2.025E-15	0.000E+00	0.000E+00	25.7
46	-5.72	-6.92	-4.80	0.000E+00	0.000E+00	24.2
47	-27.8	-45.3	-27.8	0.000E+00	0.000E+00	30.3
48	-10.4	-37.8	-9.54	0.000E+00	0.000E+00	120.
49	-1.998E-14	2.968E-15	5.742E-16	0.000E+00	0.000E+00	158.
50	20.1	-13.1	-3.11	0.000E+00	0.000E+00	188.
51	-1.770E-14	1.124E-14	2.661E-15	0.000E+00	0.000E+00	158.
52	2.60	-14.4	-3.59	0.000E+00	0.000E+00	178.
53	20.1	-13.1	-3.11	0.000E+00	0.000E+00	188.
54	1.381E-14	1.159E-14	3.014E-15	0.000E+00	0.000E+00	158.
55	4.766E-16	4.246E-15	1.795E-15	0.000E+00	0.000E+00	25.7
56	-5.72	-6.92	-4.80	0.000E+00	0.000E+00	24.2
57	-10.4	-37.8	-9.54	0.000E+00	0.000E+00	120.
58	-27.8	-45.3	-27.8	0.000E+00	0.000E+00	30.3
59	2.60	-14.4	-3.59	0.000E+00	0.000E+00	178.
60	1.154E-14	3.320E-15	9.269E-16	0.000E+00	0.000E+00	158.
61	-45.6	-27.9	-27.9	0.000E+00	0.000E+00	45.5
62	-53.7	-80.4	-51.0	0.000E+00	0.000E+00	56.0
63	-177.	-164.	-130.	0.000E+00	0.000E+00	45.4
64	-136.	-145.	-107.	0.000E+00	0.000E+00	38.4
65	-160.	-171.	-126.	0.000E+00	0.000E+00	46.6
66	-68.1	10.9	2.16	0.000E+00	0.000E+00	174.
67	-20.1	13.1	3.11	0.000E+00	0.000E+00	188.
68	85.7	0.959	0.959	0.000E+00	0.000E+00	144.
69	68.1	-10.9	-2.16	0.000E+00	0.000E+00	174.
70	-85.7	-0.959	-0.959	0.000E+00	0.000E+00	144.

71	-2.60	14.4	3.59	0.000E+00	0.000E+00	178.
72	10.4	37.8	9.54	0.000E+00	0.000E+00	120.
73	-1.127E-15	1.630E-15	1.913E-16	0.000E+00	0.000E+00	25.7
74	5.72	6.92	4.80	0.000E+00	0.000E+00	24.2
75	27.8	45.3	27.8	0.000E+00	0.000E+00	30.3
76	-66.6	-0.745	-0.745	0.000E+00	0.000E+00	165.
77	-113.	-6.09	-2.47	0.000E+00	0.000E+00	148.
78	-28.4	-20.5	-5.36	0.000E+00	0.000E+00	149.
79	-149.	-141.	-110.	0.000E+00	0.000E+00	38.2
80	32.0	-15.0	-3.48	0.000E+00	0.000E+00	191.
81	-84.6	-57.8	-54.1	0.000E+00	0.000E+00	56.0
82	-3.79	-5.29	-3.45	0.000E+00	0.000E+00	24.1
83	-26.6	-16.3	-16.3	0.000E+00	0.000E+00	27.4
84	26.6	16.3	16.3	0.000E+00	0.000E+00	27.4
85	177.	164.	130.	0.000E+00	0.000E+00	45.4
86	160.	171.	126.	0.000E+00	0.000E+00	46.6
87	84.6	57.8	54.1	0.000E+00	0.000E+00	56.0
88	3.79	5.29	3.45	0.000E+00	0.000E+00	24.1
89	149.	141.	110.	0.000E+00	0.000E+00	38.2
90	136.	145.	107.	0.000E+00	0.000E+00	38.4
91	53.7	80.4	51.0	0.000E+00	0.000E+00	56.0
92	45.6	27.9	27.9	0.000E+00	0.000E+00	45.5
93	1.602E-13	1.008E-14	3.866E-15	0.000E+00	0.000E+00	157.
94	-35.1	-57.3	-35.1	0.000E+00	0.000E+00	46.4
95	-7.04	-25.6	-6.45	0.000E+00	0.000E+00	138.
96	6.847E-15	3.359E-15	3.878E-15	0.000E+00	0.000E+00	25.2
97	-9.876E-15	-6.890E-15	-6.371E-15	0.000E+00	0.000E+00	25.2
98	113.	6.09	2.47	0.000E+00	0.000E+00	148.
99	-32.0	15.0	3.48	0.000E+00	0.000E+00	191.
100	28.4	20.5	5.36	0.000E+00	0.000E+00	149.
101	35.1	57.3	35.1	0.000E+00	0.000E+00	46.4
102	7.04	25.6	6.45	0.000E+00	0.000E+00	138.
103	66.6	0.745	0.745	0.000E+00	0.000E+00	165.
104	-2.169E-13	5.861E-15	-3.559E-16	0.000E+00	0.000E+00	157.

STRESS FORCE

NODE	X	Y	FX	FY	FZ
1	-3.8394E-04	-2.4289E-04	-73.58	-35.83	0.0000E+00
2	-3.0053E-04	-3.0053E-04	-79.61	-75.55	0.0000E+00
3	-2.4289E-04	-3.8394E-04	-37.38	-72.98	0.0000E+00
4	2.4289E-04	-3.8394E-04	-37.38	72.98	0.0000E+00
5	-2.5711E-04	-1.1606E-04	13.77	90.93	0.0000E+00
6	-1.9947E-04	-1.9947E-04	79.91	75.98	0.0000E+00
7	-1.1606E-04	-2.5711E-04	97.17	18.03	0.0000E+00
8	3.8394E-04	-2.4289E-04	-73.58	35.83	0.0000E+00
9	3.0053E-04	-3.0053E-04	-79.61	75.55	0.0000E+00
10	1.1606E-04	-2.5711E-04	97.17	-18.03	0.0000E+00
11	0.0000E+00	-2.8209E-04	28.36	1.3219E-06	0.0000E+00
12	-2.8209E-04	0.0000E+00	1.4318E-06	40.39	0.0000E+00
13	2.5711E-04	-1.1606E-04	13.77	-90.93	0.0000E+00
14	1.9947E-04	-1.9947E-04	79.91	-75.98	0.0000E+00
15	-2.5711E-04	1.1606E-04	-13.77	90.93	0.0000E+00
16	-1.9947E-04	1.9947E-04	-79.91	75.98	0.0000E+00
17	2.8209E-04	0.0000E+00	-1.4318E-06	-40.39	0.0000E+00
18	-3.8394E-04	2.4289E-04	73.58	-35.83	0.0000E+00
19	-3.0053E-04	3.0053E-04	79.61	-75.55	0.0000E+00
20	-1.1606E-04	2.5711E-04	-97.17	18.03	0.0000E+00

21	0.0000E+00	2.8209E-04	-28.36	-1.3219E-06	0.0000E+00
22	1.9947E-04	1.9947E-04	-79.91	-75.98	0.0000E+00
23	1.1606E-04	2.5711E-04	-97.17	-18.03	0.0000E+00
24	2.5711E-04	1.1606E-04	-13.77	-90.93	0.0000E+00
25	-2.4289E-04	3.8394E-04	37.38	-72.98	0.0000E+00
26	3.0053E-04	3.0053E-04	79.61	75.55	0.0000E+00
27	2.4289E-04	3.8394E-04	37.38	72.98	0.0000E+00
28	3.8394E-04	2.4289E-04	73.58	35.83	0.0000E+00

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